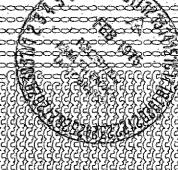


REPORT NO-4: MANAGEMENT APPROACH

(NASA-CR-143670) EARTH OBSERVATORY
SATELLITE SYSTEM DEFINITION STUDY. REPORT
NO. 4: MANAGEMENT APPROACH RECOMMENDATIONS
(Grumman Aerospace Corp.) 87 p HC \$4.75

N75-15716

Unclas 09253





EARTH OBSERVATORY SATELLITE SYSTEM DEFINITION STUDY

REPORT NO. 4: MANAGEMENT APPROACH RECOMMENDATIONS

Prepared For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GODDARD SPACE FLIGHT CENTER

GREENBELT, MARYLAND 20771

Prepared By
GRUMMAN AEROSPACE CORPORATION
BETHPAGE, NEW YORK 11714

CONTENTS

Section		Page
1 .	INTRODUCTION	1-1
2	MANAGEMENT APPROACH RECOMMENDATION SUMMARY	2-1
2.1	Program Approach	2-1
2.2	Program Management	2-2
2.3	Employment of a Flexible System Integration Team Concept	2-2
2.4	Direct Use of NASA Personnel in System Integration Functions	2-3
2.5	Contracting Techniques Between the Government and the Prime Contractor	2-3
2,6	Contracting Techniques Between the Prime Contractor and Subcontractors	2-4
2.7	Subcontracting Techniques for the Modules	2-5
2.8	Manufacturing	2-5
2.9	Test Philosophy	2-6
2.10	Documentation and Controls	2-6
2.11	Baselines and Configuration Control	2-6
2.12	Maintenance of Commonality	2-7
2.13	Summary of Cost Savings	2-7
3	MANAGEMENT APPROACH RECOMMENDATIONS	3-1
3.1	Program Approach	3-1
3.2	Program Management	3-2
3.3	Contracting Techniques Between the Government and the Prime Contractor	3-11
3.4	Contracting Techniques Between the Prime Contractors and Subcontractors	3-15
3.5	Manufacturing	3-19

CONTENTS (Cont)

CONTENTS

Section		Page
3.6	Test Philosophy	3-21
3.7	Reliability and Quality Assurance	3-27
3.8	Documentation and Controls	3-28
3.9	Requirements Specification	3-31
3.10	Customer Approval Levels	3-35
3.11	Baselines and Configuration Control	3-35
3.12	Maintenance of Commonality	3-36
4	MANAGEMENT APPROACH ALTERNATIVES	4-1
4.1	Contracting Techniques Between the Government and the Prime Contractor	4-1
4.2	Contract Types	. 4-4
4.3	Subcontract Management Techniques	4-5
4.4	Reliability and Quality Assurance	4-7
4.5	Testing Philosophy	4-11
4.6	Documentation and Controls	4-11
4.7	Baselines and Configuration Control	4-28

ILLUSTRATIONS

Figure		Page
3-1	Design-to-Cost Activity Flow	3-5
3-2	System Integration Team	3-6
3-3	Management System Operation	3-8
3-4	EOS Phase C/D Work Breakdown Structure	3-9
3-5	Program Master Schedule	3-13
3-6	EOS Program Development	3-17
3-7	EOS Flight Hardware Test Program and Flow	3-23
3-8	Flight Hardware Development and Qualification Test Summary	3-24
3-9	EOS Flight and Ground Software and Ground System Integration and Test	3-26
4-1	CM Documentation Tree	4-17
4-2	Costs of a Product Related to Specification Requirements	4-18
4-3	Document Control Levels	4-29
4-4	Optimum Baseline	4-31
	TABLES	
<u> Fable</u>		Page
2-1	Summary of Cost Savings	2-7
3-1	EOS System Integrator Team Members, a Typical Distribution	3-7
4-1	Contract Types	
4-2	EOS Subcontract Management Techniques	4-4
4-3	Reliability Issue	4-6 4-8
4-4	Quality Assurance Issues	4-8 4-11
		* **

1-INTRODUCTION

4

This Management approach for EOS has been developed at the point where the United States has completed 17 years of Space Technology experience. This period has been characterized by tremendous space advancements, the most notable of which was the landing of man on the moon. But equally or more complex and demanding in both the technical and management areas have been the wide range of observatory, scientific and communication satellites that have been developed and launched. More than 700 Space launches were made during this 17-year period. In short, the United States has met the challenges of space and overcome many of its obstacles.

Included among the technical accomplishments during this period is the development of Systems Engineering and System Management techniques, new standards in reliability and quality control and further perfection of fabrication, integration, and testing techniques. All of these elements have contributed to produce a wide range of hardware which is qualified, tested, and proven for use in the space environment. During this time, hundreds of thousands of people were trained to work in the demanding and complex space environment, and they have demonstrated their capability with a near-flawless record of space flights.

We are now faced with new challenges to continue to advance technology and improve management techniques in a new environment: that of constrained cost. The application of the lessons learned during the early years of space are now being directed to this new challenge.

This report recommends a management approach which will meet the challenge of a constrained cost environment. The requirement of this study has been to explore management approaches to achieve a low cost program. Suggested areas for study include contracting techniques, test philosophy, reliability and quality assurance requirements, commonality options, and documentation and control requirements.

To prepare a data bank for management approaches, interviews were held with personnel experienced in the management of programs covering a wide range of requirements and products. NASA, DOD, DOT and commercial programs were reviewed for alternate management approaches.

Functional areas such as manufacturing, program planning and control, reliability, quality assurance, test, contracting, subcontracting and configuration/data management have been examined for alternate methods of doing business in a way that would result in a lower cost or a more efficient program with emphasis on the requirements of a program such as the EOS. A publication search has been conducted to determine what experiences and recommendations would contribute to this study.

With this 'data bank' in hand, we have looked at the EOS program to determine which areas may be most suitable for the application of alternate approaches, and what management techniques could be applied to most effectively manage the program.

This report describes our recommended management approach, and is presented in the following order:

- Section 2, Management Approach Recommendation Summary
- Section 3, Management Approach Recommendations
- Section 4, Management Approach Alternatives.

2-MANAGEMENT APPROACH RECOMMENDATIONS SUMMARY

2.1 PROGRAM APPROACH

We recommend that the Earth Observatory Satellite (EOS) Program and the follow-on earth observation mission programs be conducted in a controlled target cost environment. In this environment, the program approach must ensure program requirements are met within allocated budgets.

Since the EOS program has relatively low production volume, and development cost is a major fraction of total program cost, the recommended program approach is Design-to-Cost (DTC) on a total Program Acquisition Cost basis.

The DTC program acquisition approach offers specific advantages in assuring that essential program requirements are controlled within allocated budgets. This approach requires innovative designs and functional concepts. It establishes the mechanism by which cost visibility is provided both to designer and management and requirements/cost incompatitibilies can be directed for higher level resolution. Cost/schedule/performance tradeoffs are conducted above minimum essential performance requirements. The net result is a lower risk program, and will maintain a total program cost within prescribed limits by designing to established cost goals and trading performance against cost for selected program requirements. This approach will reduce the cost of the EOS-A and -A' development by approximately \$11 million.

In the DTC approach, system definition studies will have established program requirements and DTC goals. Program requirements will be categorized as mandatory or desirable. The DTC goals will be target budgets for major program WBS elements, such as Spacecraft, Instruments, Ground Station, Data Processing, etc. Where the program implementation produces an out-of-tolerance condition, the problem will be resolved by re-allocation between WBS elements and/or modification of desirable requirements. The net effect will be to maintain a total program cost within prescribed limits by designing to established cost goals, and trading performance against cost for selected program requirements.

2.2 PROGRAM MANAGEMENT

To manage the program implemented in accordance with the DTC approach, we recommend a System Integration team headed by a centralized program manager which we have designated as the System Integrator. This program manager, responsible to the NASA/Goddard EOS Project Manager, is the system contractor for the Basic Spacecraft, Control Center and Mission Controls, Mission Peculiar Spacecraft, Central Data Processing Facility and Low Cost Ground Station. In addition to the above responsibilities, the System Integrator is responsible for assessing the performance of the Instrument and System GFE contractors. The scope of this assessment includes cost, schedule, and technical performance. Where cost, schedule, or technical problems develop that cannot be handled within the latitude of the specific contract, the System Integrator will perform an in-depth analysis of the problem, conducting cost/performance/requirements trades as necessary. Resultant recommended program modifications to maintain total program costs within established goals are forwarded by the System Integrator to the NASA EOS Program Manager for review, approval and implementation.

2.3 EMPLOYMENT OF A FLEXIBLE SYSTEM INTEGRATION TEAM CONCEPT

We envision the System Integrator in his total program role functioning with a working team. This working team, under System Integrator leadership, will include personnel from NASA/Goddard, user groups, GFE contractors, and the instrument contractors.

This team concept differs from normal management approaches in that it establishes a working group with the most knowledgeable personnel from each of the participants in the EOS program. Each member of the team will have his responsibilities defined, and each will contribute to the program without duplication of effort.

Use of this working team will reduce documentation requirements because the various program groups will be intimately involved in program assessment and modification as active team members. Other advantages of this concept are shortened response times, and ability to vary team mix as program focus varies through the program phases. As a matter of fact, the System Integrator responsibility may very well be assigned to other contractors for follow-on earth observation missions. NASA/Goddard, System Integrator, and team member responsibilities will be detailed through contractual interface documents and memorandum of agreement.

Management of a DTC/Program Acquisition Cost program requires a total management system for effective implementation. The management system must include a DTC system whereby major WBS cost budgets are sub-divided down to the lowest level where work is performed, namely: the Work Package Level.

The management system, in addition to the DTC system, must include a cost/schedule control system and a technical performance measurement system. The cost/schedule control system monitors, on a monthly basis, cost and schedule performance at various WBS levels against established targets. Technical performance management functions in the same manner, using technical parameters as target.

2.4 DIRECT USE OF NASA PERSONNEL IN SYSTEM INTEGRATION FUNCTIONS

We suggest that the System Integration team for EOS-A and -A' consist of approx-mately 10 GSFC/NASA personnel who will contribute directly to the EOS system development by performing portions of the system design and system requirements. This approach will reduce the contractor efforts by approximately \$1 million.

MODERATE SIMPLIFICATION OF CONTROLS, DOCUMENTATION AND TEST - The System Integration team will reduce the documentation necessary for visibility and control of the EOS program by the Government. Documentation should be minimal and in accordance with contractor formats for drawings, financial reports and failure analysis - to name a few examples. The approximate savings for this approach is \$1.25 million.

LOW-COST MINIMUM RISK TEST PROGRAM - A low-cost test program, without high risk, includes system and component environmental acceptance testing at the module level; the basic spacecraft structure and modules are qualified for follow-on, as well as the basic mission; and separate component and module qualification testing. This approach will save \$1.8 million.

2.5 CONTRACTING TECHNIQUES BETWEEN THE GOVERNMENT AND THE PRIME CONTRACTOR

The contractual techniques recommended for the DTC EOS-A and -A' phase of the program considers the cost risk of the major elements of the EOS program and shares this cost risk between the Government and the contractor to reduce the program cost to the lowest level. The EOS-A and -A' phase is also planned to permit the introduction of production procurements of the Basic Spacecraft and the Low Cost Ground Station and provides alternate methods of future procurement.

The Instruments and the DMS operations for the initial flights are procured by the Government and provided to the System Integrator as GFE. The System Integrator will manage the Instrument contractors through the System Integrator team, and will resolve interfaces within the team or by an Interface Board. For any problems requiring NASA/Goddard Project Management approvals, recommendations will be provided by the System Integrator and the Instrument contractor. The System Integrator will supply the necessary assistance to the NASA/Goddard Project Manager for the procurement and interface to fully integrate the Instruments into the DTC goals. This approach will reduce the program cost for EOS-A and -A' by approximately \$15.6 million.

The System Integrator is the prime contractor for the EOS-A and -A' mission, including the Basic Spacecraft, Control Center and Mission Control, Mission Peculiar Spacecraft, Central Data Processing Facility and Low Cost Ground Station.

We recommend that this selection be made at the earliest time to begin the development of the Basic Spacecraft and to establish the System Integration of the Instruments. To expedite this selection, we recommend that a preliminary RFP be issued to the contractors for comments. This review will provide a better understanding by Goddard and the contractor when the official RFP is issued.

The competition for the EOS-A and -A' execution phase will be a management and technical competition with the DTC goals fixed from information NASA has received from the System Definition Study and the funds allotted for the program. Costs will be allocated in this proposal to assist in understanding of the management approach. Total funding and fiscal funding requirements may be established.

This contractual plan makes full use of a DTC philosophy and presents a low-cost approach to the EOS-A and -A' execution phase. It provides the structure to manage within the program funding, and the flexibility to control within fiscal year funding. An early selection of the System Integrator will assist in the Instrument procurement and assist in optimum planning for the Basic Spacecraft. The development of a Basic Spacecraft will also enhance future space programs by providing standard spacecraft hardware for low-cost space programs.

2.6 CONTRACTING TECHNIQUES BETWEEN THE PRIME CONTRACTOR AND SUBCONTRACTORS

Subcontracting will be conducted within DTC goals and desirable requirements will be identified.

Because the seller assumes the highest degree of risk under fixed price contracting, flexible type contracting should be minimized. Maximum use of "off the shelf" components would appear to complement the use of fixed price contracting. Flexible-type contracting would be used on a selective basis. Where practical, individual subcontracts would be segmented to isolate the areas of uncertainty that lend themselves to flexible pricing; if necessary, a delay in contracting of later phases until definition is sufficiently clear to permit firm pricing is thus possible.

Pooling procurement of critical components common to several subcontractor's equipment has been found beneficial from a cost, schedule, and quality viewpoint. In these instances, Grumman and the Government can benefit from the lower cost resulting from larger volume procurement, as well as maintain greater control over uniform quality of the parts.

As part of the evaluation process of all seller proposals, a risk analysis will be prepared. This analysis will identify specific areas of risk in schedule, cost, and technical performance. In instances where competitive procurement is indicated, this analysis will become part of the selection criteria. In addition, the analysis will provide the basis for planning the procurements in a way that minimizes program impact.

To minimize total program cost by maximum use of available Government supplies and services, the Government will be considered a potential supplier in areas such as special test equipment, residual flight hardware, engineering services, and test facilities. Program requirements in these areas will be by the System Integrator team to ensure taking advantage of opportunities that may exist. It is estimated that 10% of the procurement cost may be saved by this approach.

2.7 SUBCONTRACTING TECHNIQUES FOR THE MODULES

For the design and development of the modules, a comparison between development by the prime contractor or by the prominent supplier of the module components indicates a 15% savings if the module is developed by the prime contractor. This is based upon data on the EOS Attitude Control System Module. An additional 15% may be saved by substituting components from a wide variety of suppliers. In the production phase of the modules, no significant difference in cost is indicated.

2.8 MANUFACTURING

Manufacturing techniques and procedures recommended for the DTC EOS Program to reduce the manufacturing segment of the overall program costs include support of Design-

to-Cost activities, maximum build for standard parts, use of a "limited production" manufacturing approach for small quantity parts, and a manufacturing Verification System to increase personnel motivation to "do it right the first time."

2.9 TEST PHILOSOPHY

The test trade studies define and evaluate the influences of the EOS design and system development approaches on the cost of Development, Qualification, Integration and Acceptance testing for the Spacecraft for the EOS Land Resources Mission and follow-on missions.

The significant areas of cost savings/impact identified by the test trade studies are:

- Savings of \$500 dollars which represent 50% of the Environmental Acceptance Test Costs at virtually no increase in risk, by combining all System and Component environmental acceptance tests at the module level
- Modularity and follow-on mission qualification requirements add \$125 thousand to the qualification test cost; however, the flexibility and savings in total test costs provided by the modular common spacecraft, over integrated dedicated spacecrafts for each mission, more than offsets the added \$125 thousand in qualification test costs imposed on the basis EOS program.

2.10 DOCUMENTATION AND CONTROLS

The low-cost management techniques for documentation and controls will provide NASA with visibility of EOS progress, and enchance mutual confidence without excessive documentation and control. The recommendations will provide NASA with all of the basic information it needs to measure and guide program performance, while simplifying and reducing the correlary cost of documentation review, ordering, delivery, storage and retrieval, specification requirements, configuration baselining, and change control. Our recommended use of the System Integrator team will reduce formal documentation to a minimum and increase visibility to a maximum. Cost savings are approximately \$1.25 million.

2.11 BASELINES AND CONFIGURATION CONTROL

For optimum baseline, the recommendations for the establishment of the product baseline are: Select the point in the program for establishment of the product baseline at or near the point of design stabilization to avoid an unnecessary and burdensome change mill. Dependent upon overall program schedule, portions of the system should be baselined independently at an optimum point for that segment.

2.12 MAINTENANCE OF COMMONALITY

One of the objectives of our study has been to provide a Basic Spacecraft which can accommodate a variety of follow-on missions. This philosophy is carried through to all aspects of the recommended hardware design, management approach, procurement plan, and test philosophy.

The basic spacecraft design is flexible enough to support the LRM, Marine Resources, Ocean Dynamics, Weather Observation and Transient Environmental phenomena. The recommended management approach provides a concept of a System Integrator which maintains a nucleus of people supplemented by the various team elements dependent on the emphasis of integration difficulty. The Basic Spacecraft contractor participation in the System Integration Team assures the continuity of experience, test and checkout procedures and techniques, and GSE from mission to mission.

2.13 SUMMARY OF COST SAVINGS

Table 2-1 summarizes the cost savings that will be attained in the categories described in the foregoing subsections.

Table 2-1 Summary of Cost Savings

CATEGORY	SAVINGS, \$, MILLIONS
DESIGN-TO-COST	\$11.0
SYSTEM INTEGRATOR TEAM NASA PERSONNEL PARTICIPATION DOCUMENTATION AND CONTROLS	1.0 1.25
• TESTING	1.80
 GRE INSTRUMENTS & DMS OPERATIONS 	15.60
TOTAL	, \$30.65 MILLION

4T-1

3 - MANAGEMENT APPROACH RECOMMENDATIONS

3.1 PROGRAM APPROACH

4

It is recommended that EOS program and the follow-on earth observation mission programs will be conducted in a controlled-target cost environment. In this environment the program approach must ensure that program requirements are met within allocated budget.

Experience has shown that program requirements within specified ranges can be obtained within specific budget costs. Although programs have achieved these results most commonly through a Design-to-Cost (DTC) approach to unit production costs, they have achieved similar results through a DTC approach for the total program. Since the EOS program has relatively low production volume and development cost is a major fraction of total program cost, the recommended program approach is Design-to-Cost on a total Program Acquisition Cost basis. Program acquisition offers specific advantages to insuring that essential program requirements are controlled within allocated budgets. This approach requires innovative designs and functional concepts. It establishes the mechanism by which cost visibility is provided both to designer and management, and requirements/cost incompatibilities can be directed for higher level resolution. Cost/schedule/performance tradeoffs are conducted above minimum essential performance requirements. The net result is a lower risk program because of the

- Tendency to utilize proven hardware of known cost
- Flexibility to modify requirements and trade performance versus cost
- Synergistic effect of the two foregoing elements
- Active participation of customer personnel in performance/cost trades to assure that maximum cost obligations are not exceeded.

The DTC/Program Acquisition Cost approach may seem to have the disadvantage of discouraging incorporation of new technology into spacecraft applications. Obviously, it requires frequent meetings and communication between customer and contractor, contractor and his subcontractors, and contractor and associate contractors. Furthermore, program requirements must be categorized as mandatory or desirable. Lastly, the DTC

approach requires the availability and utilization of a management system to provide the cost motivation and program status key.

Although on the surface a management system which requires relatively more discipline and formality may seem costly, inhibit flexibility, and therefore be a disadvantage, our recent experience with similar systems indicates the reverse is true. Our experience, giving full consideration to the advantages and disadvantages of the DTC/Program Acquisition Cost approach and the requirements of the EOS program/system, makes us recommend the application of this approach based on its ability to best satisfy the particular characteristics of the EOS program.

In our approach, system definition studies will have established program requirements and design-to-cost goals. The program requirements will be categorized as mandatory or desirable. The DTC goals will be target budgets for major program WBS elements such as Spacecraft, Instruments, Ground Station, Data Processing, etc. Where the program implementation produces an out-of-tolerance condition, the problem will be resolved by re-allocation between WBS elements and/or modification of desirable requirements. The net effect, then, will be to maintain a total program cost within prescribed limits by designing to established cost goals and trading performance against cost for selected program requirements. This approach will reduce the cost of the EOS-A and -A' development by approximately \$11 million.

3.2 PROGRAM MANAGEMENT

The program, implemented in accordance with the approach described above, would be managed by a centralized program manager whom we have designated as the System. Integrator. This program manager, responsible to the NASA/Goddard EOS project manager, is the basic system contractor program manager. He will have overall responsibility for the basic system, including the Basic Spacecraft, Control Center and Mission Controls, Mission Peculiar Spacecraft, Central Data Processing Facility and Low Cost Ground Station. In addition to the foregoing responsibility, the System Integrator is also responsible for assessing the performance of the Instrument and System GFE contractors. The scope of this assessment includes cost, schedule, and technical performance. Where cost/schedule or technical problems develop that cannot be handled within the latitude of the specific contract, the System Integrator will perform an in-depth analysis of each problem, conducting cost/performance and requirements trades as required. He will then recommend program modifications to maintain total program costs within established

goals to the NASA EOS Program Manager for review and approval, whereupon he will implement them. The System Integrator concept will also be effective if any program requirement or projected cost reaches an incompatible impasse. In this instance, the System Integrator would flag the problem, identifying potential alternate solutions for early corrective action by the NASA EOS Project Manager. This concept of program management is shown in Fig. 3-1.

We envision the System Integrator in his total program role functioning through a working team concept. Under the System Integrator leadership, this team will include personnel from NASA/Goddard, user groups, GFE contractors, and the Instrument contractor. This team concept differs from normal management "team approach" in that it establishes a working group with the most knowledgeable personnel from each of the participants in the EOS program. Each member of the team will have his responsibilities defined; each will contribute to the program without duplication of effort. The team makes it possible to address all functions of the EOS program, and either resolve program problems or conduct the in-depth analysis/trades necessary to formulate problem-solving recommendations for the NASA/Goddard project manager. The team for EOS-A and -A' is shown on Fig. 3-2.

The working team concept will reduce documentation requirements because the various program groups will be intimately involved in program assessment and modification as active team members. Other advantages of this concept are shortened response times and ability to vary team mix as program focus varies through the program phases. As a matter of fact, the System Integrator responsibility may very well be assigned to other contractors for follow-on earth observation missions. NASA/Goddard, System Integrator, and team member responsibilities will be detailed through contractual interface documents and a memorandum of agreement. A typical distribution for several different missions is shown on Table 3-1.

In addition to the normal expertise contributed by Government personnel, other tasks directly applicable to the EOS program will be performed by Government team members. Verification requirements definition/planning review, residual flight and ground support equipment survey for EOS use, and cost effective utilization of Government facilities are examples of the tasks which could be performed. This direct use of NASA personnel will reduce contractor cost by about \$1 million.

Proposed utilization of Government facilities is the type of recommendation that would be made to the NASA/Goddard project manager. The System Integrator and his

team would also provide a central source of current program information to assist in future mission planning by the NASA/Goddard project manager and other Governmental agencies.

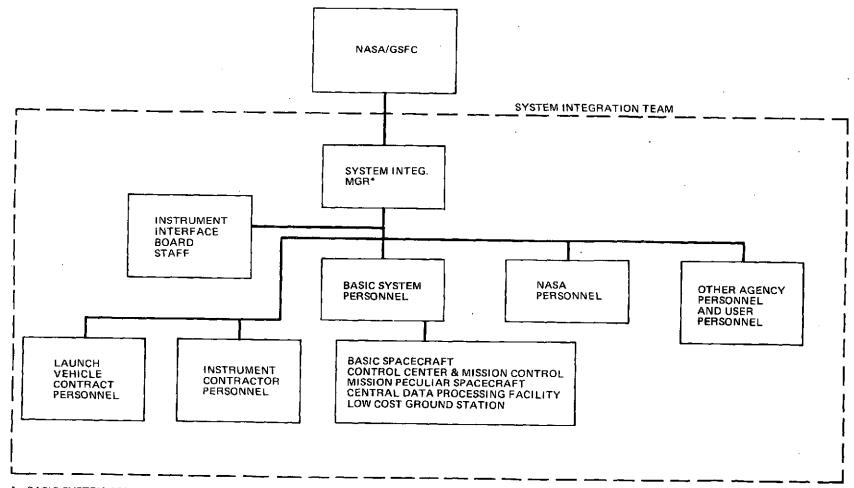
Management of a DTC/Program Acquisition Cost program requires a total management system for effective implementation. The management system must include a DTC system wherein major WBS cost budgets are subdivided down to the lowest level where work is performed: the Work Package Level. The DTC system must provide budget visibility for design, manufacturing, test and procurement personnel as well as program management personnel. It must provide the cost visibility necessary for design iterations and innovative trade studies to be performed to establish configuration and detail designs that are consistent with allocated budgets. Designers must have total responsibility for both cost and performance of their work packages. To efficiently carry out these responsibilities, they are armed with tools such as Designer's Cost Manuals, Equipment Data Bank, etc. These tools provide the designer with the capability to estimate the cost of a particular design prior to release of a design for manufacturing, procurement, and test activities. This system also provides the capability of flagging for higher level action those areas where budgets/requirements are incompatible.

The management system, in addition to the DTC system, must include a cost/schedule ule control system and a technical performance measurement system. The cost/schedule control system monitors, on a monthly basis, cost and schedule performance at various WBS levels against established targets. Allowable tolerances are established for each target and related to the current, cumulative-to-date, and at-completion time periods. If cost and/or schedule performance go out of the established tolerance, program management must document the condition and successfully close it via a variance analysis report.

The technical performance measurement system is comparable to the cost/schedule control system. Technical performance measurement parameters are established with expected results and allowable tolerances. The particular parameters selected for performance measurement include key parameters for items such as system performance assessment, customer's performance priorities, mission success criticality, and contract demonstration incentives. These items are tracked monthly; the specific parameters (for example, spacecraft weight, mean mission duration, power amplifier, power output, etc) are measured against allowable thresholds. Out-of-tolerance conditions require documentation and corrective action comparable to that of the cost/schedule control system.

3-198 4-1

Fig. 3-1 Design-to-Cost Activity Flow



BASIC SYSTEM CONTRACTOR FOR EOS A, A'. FOR FOLLOW-ON MISSIONS MAY BE OTHER CONTRACTOR OR AGENCY.

3-200 4-2

Fig. 3-2 System Integration Team

	EOS A AND A' LRM	OPERATIONAL LRM	MARINE RESOURCES	WEATHER OBSERVATION
SYS. INTEG-CONTR. (2) GOVERNMENT	20	20	30	30
NASA/GSFC LOW COST SYS.(1) JPL DEPT INTERIOR D. AGRICULTURE NOAA, D. COMM. NASA/ULO (1) SCIENCE CONSULTANTS (2) INSTR. CONTR. BASIC SPACECRAFT LAUNCH VEHICLE (1)	15 1 - 2 2 - 1 2 4 INCLUDED IN SYSTEM INTEGRATION	5 1 5 2 1 2 5 2	2 1 2 5 1 2 4 2	10 1

⁽¹⁾ PART TIME (2) EQUIV ME

3-199

4

4T-2

The management system operation for this approach, integrating the DTC, Cost/Schedule control, technical performance measurement systems, is shown in Fig. 3-3. While this program approach and management system should be applied to the total program and to the major WBS elements, certain major WBS elements (such as the launch vehicle) do not lend themselves to a DTC approach for program acquisition cost. Nevertheless, this does not preclude handling the total program on the recommended approach, nor does it exclude the application of this technique to those major WBS elements that do require significant design and development.

We recommend that the existing format of the contractor's performance system be utilized to provide the inputs required for the System Integrator program management.

Key elements in our program management are the Work Breakdown Structure (WBS), the Program Schedule, and the Action Center. The WBS provides the basic task structure to identify and define all program tasks and to establish summary levels for financial, manpower, and procurement planning. Reports to NASA/Goddard for cost and schedule performance, at one level below the Goddard project report to Goddard management, and will be in accordance with the WBS. The WBS planned for the EOS program is detailed in Fig. 3-4.

Relative to schedule, the EOS program has numerous interface functions that must be defined to assure successful accomplishment. The System Integrator must be given

EQUIV. MEN MIX CHANGES BASED ON MISSION .

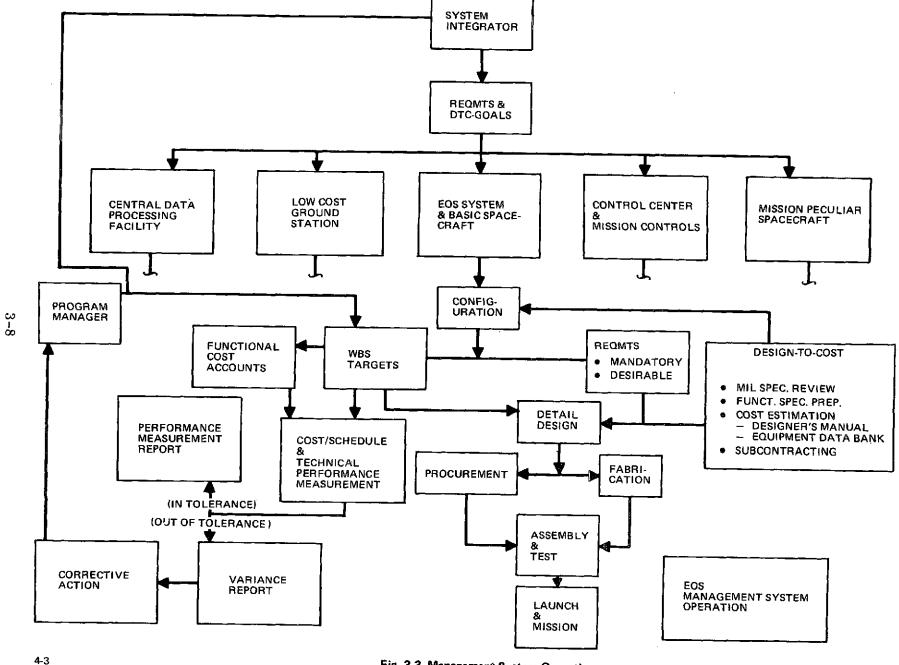


Fig. 3-3 Management System Operation

Page intentionally left blank

the time to initially schedule the various activities so that an optimum schedule can be established for each element of the EOS program. Planning must be based on realistic schedules for the events and within the DTC funding goals. The System Integrator and team members reschedule events, subject to NASA/Goddard project manager approval, to perform within DTC goals and to adjust to program problems, funding constraints, and user requirements. The recommended EOS schedule based on current program assessment is shown in Fig. 3-5.

The Action Center is recommended as the most cost effective way to display EOS program plans, status, and trends. This is a working session area displaying cost, schedule, and technical performance data for the total EOS program. Here, lower level WBS data is available to Goddard in support of the top level report.

3.3 CONTRACTING TECHNIQUES BETWEEN THE GOVERNMENT AND THE PRIME CONTRACTOR

The contractual techniques recommended for the Design-to-Cost EOS-A and A' phase of the program and shares this cost risk of the major elements of the EOS program and shares this cost risk between the Government and the contractor to reduce the program cost to the lowest level. The EOS-A and A' phase is also planned to permit the introduction of multiple procurements of the Basic Spacecraft and the Low Cost Ground Station, and provides alternate methods for future procurement.

The Instruments and DMS operations for the initial flights are procured by the Government and provided to the System Integrator as GFE. The System Integrator will manage the Instrument contractors through the System Integrator team and will resolve interfaces within the team or by an Interface Board. For any problems requiring NASA/Goddard project management approvals, recommendations will be provided by the System Integrator and the Instrument contractor. The System Integrator will supply the necessary assistance to the NASA/Goddard Project Manager for the procurement and interface to fully integrate the Instruments into DTC goals. This arrangement will reduce EOS program cost by approximately \$15.6 million.

The candidate Instruments for the EOS program are in high risk and low risk categories. The Thematic Mapper, HRPI, PMMR, SAR, SEOS and Solar Maximum have a higher development risk; it is recommended that cost type contracting is appropriate. Instruments (such as the Data Collection System (DCS) and certain SEASAT instruments) are of sufficiently low risk to procure by either a firm fixed price contract or a fixed price incentive contract.

The Launch Vehicle, Shroud, FSS, MEMS and modifications to the Data Acquisition Station are to be procured under the normal Government procurement practices. As members of the System Integrator team, representatives of these procurements will participate in the EOS program at the associate contractor level; the funding for these efforts will be part of the System Integrator DTC goals.

The System Integrator is the prime contractor for the EOS-A and -A' mission, including the Basic Spacecraft, Control Center and Mission Control, Mission Peculiar Spacecraft, Central Data Processing Facility and Low Cost Ground Station.

We recommend that this selection be made at the earliest time to begin the development of the Basic Spacecraft and to establish the System Integration of the Instruments. To expedite this selection, we recommend that a preliminary RFP be issued to the contractors for comments. This review will provide a better understanding by Goddard and the contractor when the official RFP is issued.

The competition for the EOS-A and -A' execution phase will be a management and technical competition. The Design-to-Cost goals will be fixed from information NASA has received from the System Definition Study, and from the funds allotted for the program. Costs will be allocated in this proposal to assist in the understanding of the management approach. Total funding and fiscal funding requirements may be established.

A cost-type contract should be used for this procurement. In accordance with the objectives of a DTC program, and as required by the System Integrator responsibility to manage within the DTC goals, cost tradeoffs will be a continuous requirement. A specific incentive goal could be provided for this management effort if it can be clearly defined and measured, and will not hamper the trades which might be required during the program.

Several candidates for fixed price contracting are identified with alternate procurement techniques. The Basic Spacecraft, Modules and the Low Cost Ground Station may be procured by fixed price contracts following their development. For follow-on missions, the Basic Spacecraft or selected Modules can be procured by the Government and supplied to a System Integrator GFE (Option A), or a procurement package including drawings and specifications which can be supplied for use by the System Integrator (Option B). The Low Cost Ground Station can be procured similarly. The Low Cost Ground Station can be procured by the Government for use by the users (Option A), or the procurement package could be provided for the use of the user (Option B).

n Maria Modrou	Fig. 3-5 Program Wast
-	er Schedule

HOGRAM MILESTONES		1976	1977	1978	1979	1980	1981	1982
)	——— <u> </u>	,		A LAUNCH EUS-A	oes	<u> </u>	
ATP TO CAPTURE SEASA	AT-A MISSION	ATP (EOS A - A1)	^	J	Δ		 0	1
		ALDH V	СВН			A LAUNCH EOS-A	OPS	-0
			.	OUAL INSTRINEOD				,
				,	A INSTH	FOR AT IMPLIA		
		<u> </u>		V arc) 	Erós Ar INSTH REGID		}
ESIGN DEVELOPMENT QUALIFICATION								
	L	-	<u>. </u>					
1			COMP QUAL 1EST	COMPONENT FAB				
	Ì	1						
		•	COMP	↓ ↓				
				FLT S/C COURT. (EOS A & A)				
==		-	MODULE DESIGN		,	ĺ		
	<u></u> -		MODULE FAR B ASS'Y MODULE MASS REPS INS	TALLATION				
		<u></u>	MODULESTRUCTURE	DEVEL & ACCUSTIC QUAL VACUUM DEVEL TEST				
		-5		ACCOUNT DE VEL TEST		(,	,
		¬+	STRUCT & TOOLING DESIGN					
	-T	- -	5/C STRUCTURE FA	HE & ASS'Y MASS REPINSTALLATION	•			
		τ,	STRUCTURE LOA	OS ACCEL TEST ISTRUCT & MODULES				
4		- 4 . ·	MECHANICAL	ILRM CONFIGI VIBRATION & SHOCK (LRM CONFIGIT) (EV [LRM CONFIG]			د د د مستهد	
		· 43	RECONFIGURE	MSTR MASS REPS FOR WORST CASE SO	LOW ON MISSIONS			
		4	MECHANI	CAL VIBRATION & SHOCK			•	
			ACOUST SEPARA	ATION & DEPLOYMENT QUALITEST		1		1
	. [<u></u>	SEPARATION & DEPLOY DEVEL TESTS	MODULE WIRING & COMPONENT IN INSTRUNTEG & DRS FUNCT TES	f			
	ļ		[1]	THERMAL VACUUM INCLUDE	SHOCK]		
			ĹĴ	POST T/V SYS TESTS				
		====	FLIGHT SOFTWARE DESIGN	♦ (AVAILABLE FOR SHUTT	LE GND & FLT TESTS AND/OR MODU	LE COMPONENT REFURBI		
			DEVE	L & INTEG SOFTWARE/HARDWARE LAG	(ENG MODEL AOP)			
,		<u> </u>	<u>i</u>	SOFTWARE/HARDW	ARE (NTEG]		
		*	QUAL CADM MODULE SO	FTWARE	•	ļ		
	J			*,		'		
	,				,			
		=======================================	SCALE MODEL FAB	ANTENNA PATTERN TESTS		İ	,	
			FULL SCALE X BAND	ANTENNA MODEL FAB BAND ANTENNA PATTERN TESTS				
	1		, <u> </u>	TEGIG				
	· 				, 			,
SPACECRAFTS	[<u></u> I	MODULE FAB ASSY & WIT	eing	 _		
				COMPONENT INSTALL	ATION & INTEGRATION			
				MODULE	ENVIRONMENTAL ACCEPT, TEST			
					NVIRONMENTAL TEST MODULE C/O			
		ļ	`—— —— ————————————————————————————————	SPACE	FT STRUCTURAL FAS & ASSY CRAFT WIRING & C/O		İ	
				SPA	CEGRAFT MODULE IN FEG & FUNCT	C/O		
	ļ		· iš	EASAT MODULES	NSTR INTEG & C/O. IMP & OAS INTEG			•
	} —	- SEASAT BASIC SPACE	CHAFT	IMP & OAS INTEG .	OBS SYS TEST & EMC SEPARATION & DEPLOYMENT ME	1		
				IMP & INSTRUMENT & AT	WORKMANSHIP ACOUSTIC PAR	CK & SHIP		
				INSTR/IMP/DMS COMPAT	PRELAUNCH OPERATIO	NS		
		•						
	{	j		1		j		•
			BASIC SPACECRAFT NO. 1	· · · · · · · · · · · · · · · · · · ·				
				\	MODULE FAB ASS'Y & M	LATION & INTEGRATION		
		İ			\$/8 FUNCTIONAL	C/D ENVIRONMENTAL ACCEPT, TEST		
				}	Posit	ENVIRONMENTAL TEST MODULE C/O		
	1				SPACECE	AFT STRUCTURAL FAB & ASS'Y		
					SPAC	ECRAFT WIRING & C/D ACECRAFT MODULE INTEG & FUNCT C/		
	1							
	1	1			IMP & OAS INTEG .	OBS SYS TEST & EMC		
	}				IMP & OAS ENV AT	SEPARATION & DEPLOYMENT MECH		
					IMP & INSTRINTED & AT I	WORKMANSHIP ACOUSTIC PACK PRELAUNCH OPERATIONS	& SHIP	• .
			BASIC SPACECHAFT NO. 2				1	
MISSION OPS								
				161				•
	- 1	<u> </u>	DMS & CC FINAL QES	OMS & CC HOWE PROCUREMENT	r			
			<u> </u>	DMS & MOS	DMS & CC HOWE SOFTWE INTEG			
				INSTRIC/O	SIMULATIONS THE & NET	C/O		
					INSTRIC/O	2 S/C OPS TNG & NET C/O	S/C NO. 1 DPS	
	1	1			1			S/C NO. 2 OPS

The DMS operations (including the Mission Control, Data Processing operations and support) should be contracted by a time-and-material or labor-type basis. Each contract should be by individual contracts, rather than by the System Integrator for maximum direct procurement - a DTC approach is not of significant value during this phase of the contract.

The overall contractual plan makes full use of a DTC philosophy, and presents a low-cost approach to the EOS-A and -A' execution phase. The plan provides the structure to manage within program funding, and flexibility to manage within fiscal year funding. Also, an early selection of the System Integrator will assist in the Instrument procurement as well as in optimum planning for the Basic Spacecraft. The development of a Basic Spacecraft will also enhance future space programs by providing standard spacecraft hardware for low-cost space programs. Figure 3-6 presents the EOS program development flow. A candidate for separate procurement is the Basic Spacecraft, which may be developed earlier and separate from other elements of this EOS program.

3.4 CONTRACTING TECHNIQUES BETWEEN THE PRIME CONTRACTORS AND SUB-CONTRACTORS

Our review of subcontracting techniques and the goals of a DTC program has resulted in the following specific recommendations for implementation of an effective EOS procurement plan.

Changes are the most frequent cause of cost growth and schedule delays in major sub-contracts. Changes are often the result of placing a priority on scheduling that appears to justify incomplete requirements definition at the time of initial authorization to proceed. A significant reduction in change activity can be achieved by delaying major, high-risk procurements until the systems engineering effort has provided more precise performance and interface requirements; this approach also reduces cost and provides significantly more accurate schedule planning.

Since the seller assumes the highest degree of risk under fixed price contracting, flexible type contracting should be minimized. Maximum use of 'off the shelf' components appears to complement this basic policy. In areas where development or modification could make the use of fixed price contracting counter-productive in terms of program interests, flexible type contracting can be selectively used. Where practical, individual subcontract would be segmented to isolate those areas of uncertainity that lend themselves to flexible pricing and, if necessary, delay contracting of later phases until definition is sufficiently clear to permit firm pricing.

Similar to the problem regarding changes resulting from lack of complete systems engineering and requirements definition at program inception, changes can also occur as the result of a precipitous release of the production phase. Production should be delayed until development testing provides clear assessment of the final design configuration. Special emphasis should be applied to a careful review of produceability and manufacturing processes prior to production release.

In concert with the policy of maximum use of fixed price subcontracting, the specifications should convey maximum responsibility to the subcontractor. Maximum responsibility is conveyed by a minimum of detail. One extreme would be to procure equipment "suitable for the use intended" by defining "the use intended". Conversely as specific design detail and other restrictive requirements are added, the prime contractor assumed responsibility for the effect of this detail and creates a scope envelope that is more subject to contractual change. However, all critical performance, test and interface parameters will be clearly defined.

Experience shows that seller's responsibility for the successful performance of his equipment can be effectively extended through installation and checkout in the end article. This contrasts with the traditional method of basing acceptance upon inspection and test at source or incoming inspection at destination. Selected sellers would be contractually obligated to provide personnel and equipment to participate in "shepherding" their flight hardware through spacecraft installation and checkout.

Another method of providing motivation to selected sellers throughout their subcontract performance will be to provide seller opportunity to earn additional fee based upon the performance of seller equipment in orbit.

Early and continuing emphasis will be applied to produceability. Initial design reviews will incorporate specific attention to this discipline to ensure cost effectiveness and uniform repeatability of the product. Manufacturing methods and processes will receive early attention to provide confidence prior to production release.

An area of significant cost in major equipment procurements is documentation. The traditional approach to documentation has been to pass down to sellers the applicable portions of prime contract requirements, including format and depth of detail. We recommend that documentation requirements for each procurement be "tailored, "taking into

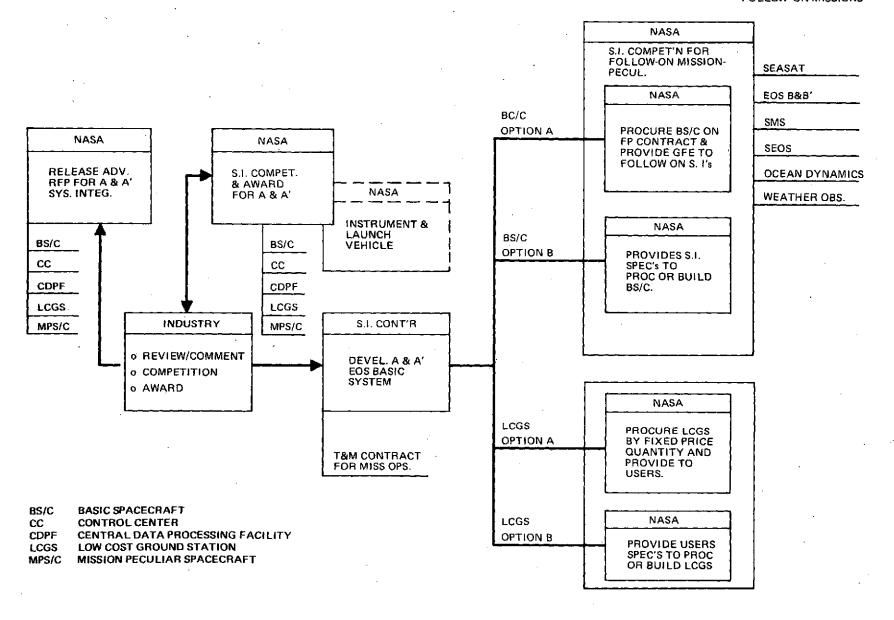


Fig. 3-6 EOS Program Development

account the specific use to which it will be put, quality, and extent of existing data and formats currently employed by the seller that may differ from specification requirements. Emphasis shall be placed upon the practical needs of the potential users and not on rigid conformance to uniform standard requirements.

Responsibility for monitoring seller adherence to the quality assurance provisions of a Grumman subcontract should rest with Grumman. Specifically, acceptance of an end product at a seller's plant should be at the discretion of the Grumman quality assurance representative. Providing secondary, overlapping responsibility to Government resident quality assurance personnel duplicates effort that adds to the administrative costs of the subcontract, provides dual authority for quality assurance decisions and often delays critical deliveries.

Traditionally, payments to sellers under fixed price subcontracts are based upon incurred cost (progress payments) or physical delivery of an end item. Neither of these methods provide adequate incentive to the seller in meeting the early critical milestones that are often not evidenced by physical deliveries, but which are critical to later equipment deliveries. By selectively establishing payment schedules based upon achievement of key milestones, the sellers are provided with an incentive to stay on schedule early in the program.

If under the subcontract clause of the prime contract, the Government reserves the right of prior approval in the placement of specific types of subcontracts, there should be a time limit established for this approval cycle. This will permit more precise scheduling of the procurement plan and will prevent delays that could ultimately effect equipment delivery. A time period of 10 days, after which in the absence of disapproval Grumman would be authorized to proceed, would appear reasonable.

Pooling procurement of critical components that are common to several sub-contractor's equipment has been found beneficial from a cost, schedule, and quality viewpoint. In these instances, Grumman and the Government can benefit from the lower cost from larger volume procurement, and maintain greater control over uniform quality of the parts. However, due to the administrative costs and contractual ramification on our subcontract relationship this procedure would be employed on a highly selective basis.

As part of the evaluation process of all seller proposals a risk analysis will be prepared. This analysis will identify specific areas of risk in schedule, cost, and technical performance. In instances of competitive procurement, this analysis will become part of

the selection criteria. In addition, the analysis will provide the basis for planning the procurements in such a way as to minimize program impact.

To minimize total program cost by maximum use of available Government supplies and services, the Government will be considered a potential supplier in areas such as special test equipment, residual flight hardware, engineering services and test facilities. Program requirements in these areas will be to ensure taking advantage of opportunities that may exist.

Decisions by the program CCB must be made on the basis of firm economic consideration. Where changes affect subcontractors, firm subcontract commitment as to price must be obtained prior to such decision. Budgetary estimates and lack of firm technical definition contribute to unplanned cost growth and poor cost effective decisions.

3.5 MANUFACTURING

Manufacturing techniques and procedures recommended for the DTC EOS Program to reduce the manufacturing segment of the overall program costs include support of DTC activities, maximum build for standard parts, use of a 'limited production' manufacturing approach for small quantity parts, and a manufacturing Verification System to increase personnel motivation to 'do it right the first time."

Manufacturing works closely with Engineering in trading off alternate concepts and configurations, and establishing DTC targets for the recommended configuration with the aid of a Designer's Cost Manual. As DTC targets are established, a Manufacturing plan for fabrication of EOS hardware is developed. At the conclusion of each phase, the planning data is projected and documented for the implementation of each succeeding phase.

In the development phase of the EOS programs manufacture of small quantity parts for the EOS program will use a 'limited production' manufacturing approach. The low rate of manufacture permits use of the 'limited production' approach where in shop technician skills and simple shop aids replace most of the formal detail and subassembly tooling. Tools will be provided only when essential to ensure structural integrity, meet production requirements, and maintain interface requirements between EOS modules and the EOS Launch Vehicle.

EOS parts are designed to utilize prototype manufacturing techniques, with tolerance based on prototype capabilities. Parts fabrication is simplified by producing sheet metal and machined parts from full-scale mylar or dimensional engineering drawings.

Hydraulic lines are developed from template (soft tubing) lines that have been developed and verified on the vehicle to permit use of standard tooling available, and to reduce project tooling requirements and associated costs. Electrical wiring will be built up by attaching connectors to one end of wiring that has been cut oversize from lengths established from engineering drawings. Final routing, bundling, and attachment of remaining connectors/terminals will be accomplished directly on the vehicle during final assembly. This approach has proved to be the most cost-effective on low-quantity production programs.

MANUFACTURING MANAGEMENT SYSTEMS - Electronic data processing (EDP) operating systems will be used on the EOS program. The overall systems encompasses the capability to control either low-or high-rate production programs. Operating in a reduced mode, the Manufacturing Operational Data System (MODS) provides the level of accountability required for low-rate/volume EOS type programs without incurring the high cost normally associated with major EDP systems. The MODS provides product definition in an indented parts list (IPL) and supplies inventory control, part tracking through fabrication, and automated work orders, kit lists, and back orders for assembly work releasing, MODS also provides tracking for manual (prototype) work orders that are released to initiate fabrication of parts.

CHANGE CONTROL - Minor changes to the EOS design may be implemented in the shop by 'red line' drawing changes which are made informally, with Engineering and Manufacturing management concurrence on budget and schedule impact. The 'red line' changes are coded on the shop copy and immediately incorporated on the original drawing.

Engineering Orders (EO's) will be issued for more complex changes, including the creation of new parts and/or assemblies.

MANUFACTURING VERIFICATION SYSTEM - The MVS increases personnel motivation to 'do it right the first time". Under this system, technicians are issued personal certification stamps that they use to indicate satisfactory completion and inspection of operations on the work order. Items presented for acceptance are verified by a Quality Control inspector with subsequent Quality Control inspection levels increased or decreased in accordance with shop performance.

Performance in the shops is fed back to Manufacturing management for improvement and corrective action. The verification system reduces inspection manhours up to 15%

in areas under the system, reduces repair/rework activities, and increases the quality of completed hardware.

3.6 TEST PHILOSOPHY

The total EOS Development, Qualification, Integration add acceptance test program is shown in Figure 3-5. The approach shown ties in with the basic EOS test requirements and trade studies documented in Report 3, Subsection 6.18. These studies examine the alternative approaches to satisfying both the basic LRM mission and common spacecraft test requirements at a cost saving of \$1.8 million.

3.6.1 RECOMMENDED APPROACH

- Combining all system and component environmental acceptance tests at the module level representing a cost savings of \$500 thousand, or 50% per Spacecraft of environmental acceptance test costs over the conventional, component and system environmental test approach, and at virtually no program cost, schedule, or technical risk
- Qualification of the basic spacecraft structure and modules for follow-on as well as the basic missions, to provide a level of design confidence which permits NASA to take advantage of the cost benefits of a multi-buy Spacecraft procurement plan. Based on subcontractors estimates for a 30-unit buy versus a 5-unit buy this could represent a 20% cost savings in component costs alone
- Separate component and module qualification tests to ensure that component qualification levels are adequate to cover follow-on mission environment
- Verification of the flight instrument and ground processing system compatibility and functional performance, independent from the basic spacecraft flow, and providing both a low cost approach to demonstrating the EOS mission-peculiar hardware and software flight readiness as well as maximum Integration and Test schedule contingency and flexibility
- Utilizing the high percentage of developed subsystem avionics hardware to permit elimination of a costly bench or laboratory avionics development spacecraft
- Making the systems qualification spacecraft available for performing Shuttle ground and flight EOS on-orbit resupply demonstration, and/or refurbishment for flight

3.6.2 INTEGRATION AND TEST

BASIC SPACECRAFT - The I & T program for a typical set of EOS light hardware is shown in Figure 3-7. The components are functionally tested at the subcontractor and shipped to the prime contractor for integration into the modules. Once the modules are integrated and functionally checked the modules are subjected to either acoustic or mechanical vibration, two days of thermal cycling, and a six day thermal vacuum test to verify

component and module workmanship. The current plan calls for serial testing of the modules using the same Test and Integration (T & I) station and unique software interfacing through the module remote decoders and multiplexers. Individual hardwired GSE is used for module power and monitoring of hardlines during test. The non-mission, unique on-board software will be developed, debugged, and qualified in the software development laboratory. Integration of the flight software with the flight computer will be accomplished during integration of the CDH module. Initial software required for the ACS processing during ACS module tests will be simulated from the T&I station.

Upon completion of the module level tests the subsystem modules will be integrated together, and functionally checked as a system on the flight Spacecraft back-end. At this point, we have a Basic Spacecraft ready for integration of the mission peculiar Instruments, Instrument module, mission software, and Orbit Adjust/Reaction control system module.

MISSION PECULIARS - The Instrument, IMP and Wideband antenna will be tested as a system at GSFC, using the IMS Primary Ground Station to demonstrate the flight and ground system compatibility, and prior to integration of the Instrument with basic spacecraft. Observatory/Control Center and Network compatibility will be demonstrated via RF through the WTR ground station.

Integration of the mission peculiars could directly follow the Basic Spacecraft buildup as shown in Figure 3-7, or be downstream with the Spacecraft held in controlled environment storage facilities. In the typical flow and schedule shown, the next step would be to integrate the mission peculiar hardware and software, and perform observatory level systems performance tests, including EMC. The separation and solar array deployment mechanisms are then tested. The solar array size, and potentially its deployment technique, is mission peculiar; therefore, it is performed at this point in the schedule. The separation test, however, could be performed earlier/but it is performed here as a matter of convenience. Prior to shipment of the observatory of WTR for launch, a workmanship acoustic test of the integrated observatory is shown. The observatory, in flight configuration with the exception of pyrotechnics, will be transported to WTR in the horizontal position. WTR prelaunch operations are scheduled for five to six weeks as a target since no extraordinary tasks or special tests are required at the launch site. Shuttle, Titan, and Delta launch vehicle flows all permit observatory integration with the launch vehicle about 7 to 10 days prior to launch.

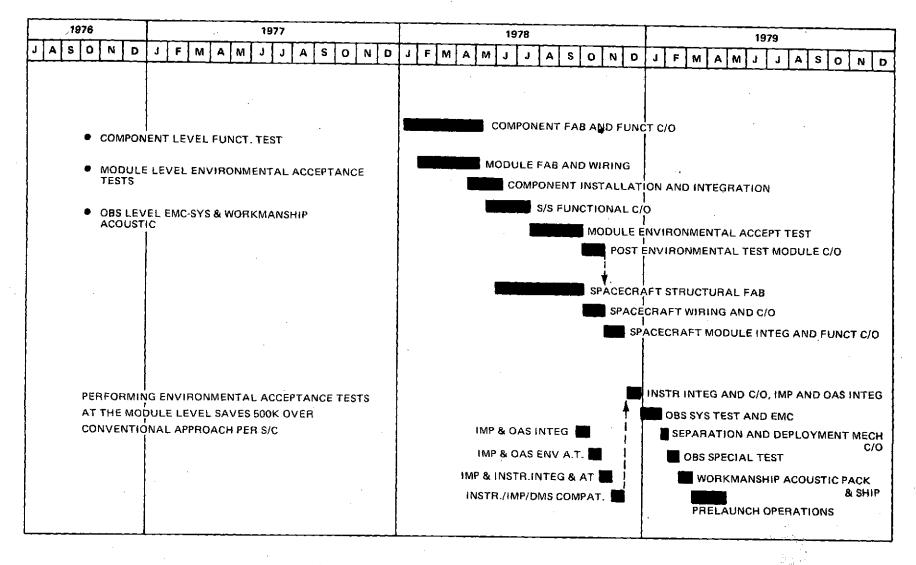


Fig. 3-7 EOS Flight Hardware Test Program and Flow

3.6.3 DEVELOPMENT AND QUALIFICATION TEST

The recommended Development and Qualification test program for the EOS flight hardware is shown in Fig. 3-8. Since it is a design goal to accommodate all missions with the same Basic Spacecraft, the recommended test program considers the basic EOS land resources mission configuration qualification as well as qualification of the Basic Spacecraft for follow on missions.

The recommended plan provides for module, thermal development and structural qualification testing at the module level. The thermal development tests are required on at least two of the subsystem modules to verify the thermal analysis model. Acoustic and mechanical vibration qualification tests are performed at the module level for two reasons: to determine component environments seen during module tests so as to evaluate module level acceptance test methods, and to qualify the basic module structure.

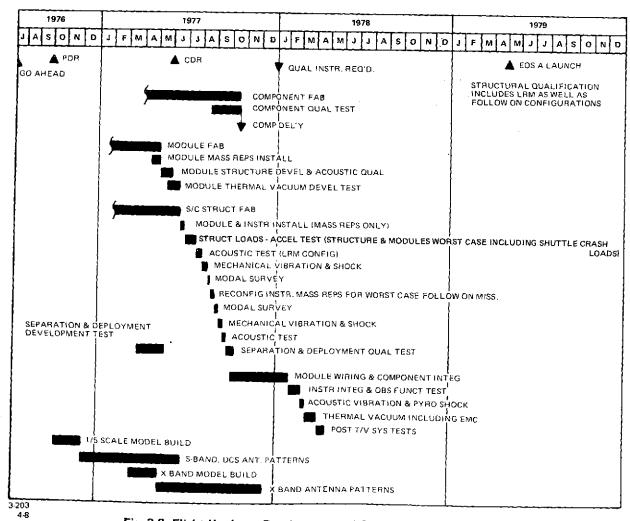


Fig. 3-8 Flight Hardware Development and Qualification Test Summary

3.6.4 SPACECRAFT

The same modules used for module level tests with the component mass representations installed will be used for vehicle level tests. The LRM OAS and IMP module configuration will be used for Observatory Structural Qualification. OAS/RCS IMP modules for follow on missions will be qualified where required at the module level. The program requirements of Report 3, Appendix C call for vehicle static tests to verify structural loads; however, based on the trades studies documented in Report 3, Subsection 6.18, a vehicle level acceleration is recommended as a more cost effective approach to verifying the module and spacecraft static strength. An early acoustic and mechanical vibration test is recommended for both the LRM and follow on configuration for two reasons:

- Provide early verification of component environmental levels to preclude down stream requal
- Permit an early evaluation of the total spacecraft environments vs the design environment for the various configurations.

The Observatory model survey is required for the cantilevered and free-free configuration for both the LRM and follow on configuration.

MECHANISMS - Qualification of the separation, and deployment mechanism as well as the basic LRM solar panel structural design is achieved during the observatory level qualification tests. Earlier in the program off line development tests of the mechanisms will be required to verify the basic design approach.

ANTENNA PATTERNS - S-Band, X-Band, and DCS antenna pattern tests are scheduled early after contract go-ahead to finalize antenna locations, and verify link analysis for the LRM configuration. These models should be maintained to verify follow-on mission antenna patterns.

OBSERVATORY SYSTEMS - Following the structural qualification the vehicle is reconfigured for Observatory Systems Qualification, including a qualification model LRM instrument consisting of EMC, Acoustic, Thermal Vacuum, RFI and pyrotechnic shock test. Vendor qualification components where available or a flight component are required for observatory level system qualification. Three and one-half months of S/S module integration is allowed for in the schedule to cover first-time integration of the subsystems.

4-9

Since paralled integration of the modules can be performed by time-sharing the T&I station, this should be adequate to debug the Basic Spacecraft subsystems and test procedures.

Completion of system qualification tests permit the qualification components to be refurbished for flight, or utilization of the entire qualification vehicle for the demonstration of shuttle resupply concepts in both ground and shuttle flight test.

INSTRUMENT INTERFACES - A Spacecraft simulator and the mission peculiar IMP module will be required to support instrument manufacturers for functional interface verification during instrument qualification and acceptance tests.

3.6.5 GROUND SYSTEMS AND INSTRUMENTS

Figure 3-9 shows the Ground System hardware and software flow for both the DMS and Mission Operations Control Center.

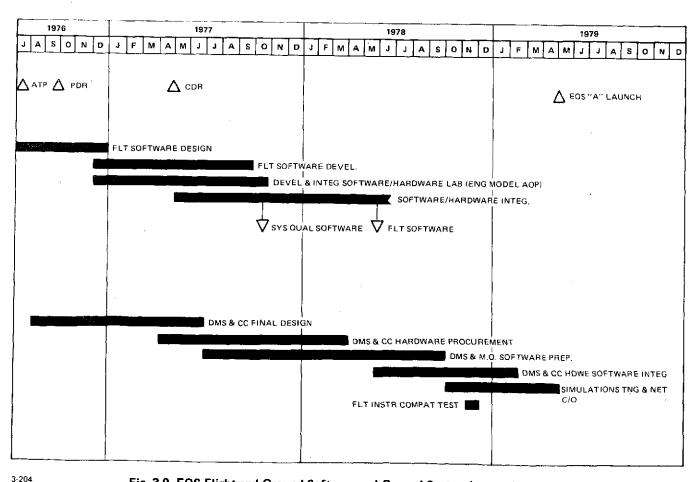


Fig. 3-9 EOS Flight and Ground Software and Ground System Integration and Test

3 - 26

INSTRUMENT DATA ACQUISITION - Instrument Data Acquisition during Observatory Qualification and Acceptance tests will be accomplished via a low-cost Ground Station front-end, which will be part of the T&I station. Observatory test tapes will be provided to validate Low Cost Ground Station field site installations. Primary ground station-observatory compatibility tests can be demonstrated by, testing the Instrument - IMP and spacecraft simulator setup at GSFC prior to integration of the instrument with the flight spacecraft, or by shipping the entire observatory to GSFC prior to delivery for WTR for launch. The cycling of the Instrument, IMP and Spacecraft simulator through GSFC was chosen since the total Instrument data train including RF is checked at minimum cost without tying up the entire T&I crew and observatory. During Observatory Systems Tests, Instrument performance will be evaluated by internal instrument calibration monitoring at the T&I station, for both wide-band full data-rate operations and the Low Cost Ground Station lower data-rate.

CONTROL CENTER - Control Center check out and personnel simulations training is recommended to be accomplished by software simulation because it provides both maximum flexibility in schedule and follow on mission reconfiguration at minimum cost.

3.7 RELIABILITY AND QUALITY ASSURANCE

The following approach is recommended to ensure the required reliability at the lowest cost. The Reliability Program plan will be a single document including the site plans; it would be updated as required by major changes, rather than undergo periodic updating. Program control and progress reports would be integrated into the design reviews. Formal reporting would be limited to significant events and problem areas. Design specifications will be prepared for each item of hardware at the system, subsystem, and component level.

Reliability predictions will be performed as necessary to support trade studies, maintainability analysis, and logistics planning. Updates will not be required for minor design changes, and predictions will not be to detailed levels within black boxes. Complex models internal to black boxes are expensive and are of questionable value.

FMEA's will be performed within the black boxes for all critical functions and to the piece part level for hazardous and mission criticality failure modes only. Program failure reporting and correction will be in accordance with contractor procedures. Additional recommendations are to include launch critical GSE in failure reporting system and selectively include other GSE. Implement a system to standardize design and fabrication processes and standardize parts. Test requirements are recommended in the test philosophy section.

The recommendations for Quality Assurance are:

- Test and inspection verification by Government inspection agency to be on a post-audit basis to reduce cost and eliminate delay. Post-audit permits the contractor to move ahead in the manufacturing/test cycle and monitored by the Government Representative
- Determine traceability requirements on basis of need. Distinguish between Critical Structural Items, Limited Life/Cycle Items, Matched Items requiring replacement in pairs, and routine less-complex items
- Introduce a material review system tailored to the significance of defect and item criticality. Delegate responsibility to a single authority. QA will implement corrective action. Government representative will exercise jurisdiction on post-audit basis.

The contractor should select workmanship standards and will be subject to continuing NASA review.

3.8 DOCUMENTATION AND CONTROLS

The low-cost management techniques for documentation and controls will provide NASA with visibility of EOS progress and enhance mutual confidence without excessive documentation and control. The recommendations will provide NASA with all of the basic information it needs to measure and guide program performance, while simplifying and reducing the correlated cost of documentation review, ordering, delivery, storage and retrieval, specification requirements, configuration baselining, and change control. Our recommended use of the System Integrator team will reduce formal documentation to a minimum and increase visibility to a maximum, with the resulting savings of approximately \$1.25 million.

Our recommendations are summarized under the following categories: Documentation Requirements, Requirements Specifications, Baseline and Change Controls.

The first topic is the methodology of establishing the requirements for documentation in the first place, Subsection 3.8.1, "Requirements Establishment and Ordering Techniques". The second topic is Subsection 3.8.2, "Documentation Formats and Management Systems Requirements" and finally, Subsection 3.8, "Documentation Processing and Review".

3.8.1 REQUIREMENTS ESTABLISHMENT AND ORDERING TECHNIQUES

The following recommendations address the area of documentation requirements establishment and ordering techniques:

- Limit the documentation ordered at contract award to the unique legally (procurement regulation) mandated items, the key documents obviously required for approval by NASA, and an accession list of all other data prepared by the Contractor as a by-product of his work scope
- Conduct review and "tailoring" of documentation requirements such as financial reports, to the specific program needs after contractor selection and before finalization of the contract when the Contractor is free from the pressure of competition and the NASA is freed from the requirement to keep things equal between competitors.
- In lieu of requirements, provide a Government/Contractor review of documentation requirements concurrent with the technical design review process to scrub and revise the contract requirements as the program unfolds. Use an approach wherein items that are "now apparently" not needed can be eliminated, and the need for contingency items can be determined with greater accuracy.
- Encourage "data minimization" by providing flexibility within NASA as well as the Contractor, for reduction of formal documentation in lieu of other means of acquiring equivalent information.

3.8.2 DOCUMENTATION FORMATS AND MANAGEMENT SYSTEM REQUIREMENTS

One reason that documentation costs are typically high is because of the expenditure of resources to formalize reports, test data, specifications, procedures, manuals, and plans. Documentation costs are incurred both directly and indirectly. The costs directly associated with providing specified data, such as the in-house identification and validation functions, are relatively obvious. Less obvious are the costs associated with requirements to comply with the multitude of management information and control systems which may be required indirectly to satisfy individual data requirements.

We recommend that the rigidity of format be considerably relaxed. Data requirements should reflect the minimum acceptable documentation that will supply the user with the depth and content of the information he needs. The Contractor should be able to satisfy most of the requirements with information that is a normal output of the management/design/development/production effort, using generally good business practices. Face-to-face verbal discussion promotes the mutual trust, respect, and teamwork that is essential to achieve EOS program objectives.

There are a number of areas where rigid format requirements can be relaxed with no adverse affect on the contract performance, end product use, or supportability. One area is the engineering drawing requirements.

Another area loosely falling under the category of format is the storage and retrieval functions of documentation management and the media of transmittal.

Emphasis should be placed on maximum use of contractor format whenever it can fulfill the "intent" of the documentation or system requirement of the Government.

Documentation requirements should take into consideration the regular review, monthly status meetings, etc, which take place as a forum for transmitting the needed information, rather than via formal reports. Minutes of such meetings could supplement many "data items".

Utilize informal working documentation - the same material that the Contractor's engineers used to make their decisions - in lieu of formal reports. Some examples of this information might be engineers notebooks, engineering layouts, and raw data sheets. Good data need not be "pretty" to do the job, and NASA personnel are technically competent to review the same data and make their conclusions in an "over-the-shoulder" or "on-the-board" environment.

Specify engineering drawings to industry standards, or at the very most, Form II Drawings to Industry Standards. The following modifications to normal drawings practices are recommended:

- Use of Engineering layouts in lieu of formal assembly and installation drawings
- Elimination of margins and zones on engineering layouts
- Eliminating rivet length callout on drawings for rivets which measure less than 1 in. long
- Less restrictive reproducibility requirements for paper copies allowing full legibility of first generation copies in lieu of fourth generation.

Replace conventional hard copy transmittal of documentation, wherever practicable, with microfiche. This recommendation is particularly applicable in conjunction with the deferred ordering or accessioning of documentation.

Do not implement requirements for more Quality Assurance imposed on documentation, and do not require DD-250's (or equivalent) for documentation. The recommended direction is to reduce not increase this type of requirement.

3.8.3 DOCUMENTATION PROCESSING AND REVIEW

The documentation processing and review recommendations are:

- All contractual data/documentation requirements should be carefully screened by NASA prior to imposition on the contractor to assure that documentation that does not directly affect NASA's interests, or has a higher level requirement controlling it, be submitted for information rather than for approval.
- Only design concept drawings be specifically signed and approved by NASA.

 Manufacturing drawings should not require Government Representative signature; such signature does not connote approval, and does not relieve the Contractor of his overall responsibilities.

3.9 REQUIREMENTS SPECIFICATION

For a given procurement, be it NASA procuring from a contractor, or a contractor purchasing from a subcontractor, the way that the requirements for the item being purchased are specified can have a dramatic impact on the cost of the item. The cost can be incurred to a greater or lesser degree dependent upon the choice of the type of specification, the matching of the content to the specification function, and the level of customer involvement and approval.

In addition to these factors, there are, of course, savings that can be realized by intelligent specification preparation practices which minimize the cost of maintaining the documents as changes occur.

For our recommendation, we have focused on the following specifications:

- <u>Development Specifications</u> Define the "design-to" requirements for an item to be developed. The essence of this type of specification is the items performance, form factor and other pertinent technical considerations
- Product Specifications In addition to the performance and design requirements, these specifications define the "build to" and "test-to" requirements. They may be part II of a two-part specification, the first part of which is the Development Specification
- Materials and Process Specifications State the requirements for materials and techniques and procedural requirements applicable to materials or fabrication processes. These are subsiduary specifications which are referred to in the higher-tier specifications, or on the implementing engineering drawings. Test specifications are included in this category.

Our recommendations related to specification-type and content are presented in the paragraphs that follow.

4

Whenever possible, utilize Functional Specifications stating performance only as opposed to Detailed Design Requirements in accordance with the following guidelines:

- Use Development (Design Control) Specifications for any item below the system level whenever it is considered sufficient to specify performance only (as opposed to fabrication)
- Limit use of Design Control Specifications to those items where it is necessary to specify performance as a first step in developing a Product Fabrication (detail design) Specification. (The transition to a fabrication specification is greatly facilitated by the existence of a Development (Design Control) Specification.)

Performance requirements should be stated in quantitative terms only, that is, in terms of numerical inputs and outputs including permissible tolerances under various operating conditions as applicable. This is the only way performance values and tolerances can be established and verified for use in the attendant test or checkout procedure. In the case of the specification defining the preproduction configuration, these values and their tolerances serve as the basis for establishing the performance criteria of the equipment under the various environmental conditions of the qualification test.

Any development specification should be void of "how-to" design details. Such details will only inhibit the designer's function by telling him how to do something instead of stating the end result he is required to achieve. This type of information belongs in the fabrication specification. The development specification should not contain philosophy and descriptive matter; rather, it should devote itself to exact statements based on a black-box concept (that is, list only inputs, outputs, and interfaces without concern for principles of operation). One exception would be when, for a valid technical reason, part of all of the detail design has to be dictated. In general, specification of design details should be kept to a minimum.

Product Fabrication (detail design) Specifications are applicable to any item below the system level (including computer hardware), and are oriented toward procurement of a product through specification of primarily fabrication (detail design) requirements. This specification should be used for second source procurement or re-procurement (that is, when it is necessary to make available a design disclosure package) to control the interchangeability of lower-level components and parts, and when service, maintenance, and training are significant factors. This specification shall state:

- A detailed description of the parts and assemblies of the product, usually by prescribing compliance with a set of drawings
- Those performance requirements and corresponding tests and inspections necessary to assure proper fabrication, adjustment, and assembly techniques.

In instances where a Development (Design Control) Specification has been prepared, specific reference to the document containing the performance requirements for the item shall be made in the fabrication specification. Tests normally are limited to acceptance tests in the shop environment consisting of selected performance requirements and verifying tests. Preproduction-type or periodic tests to be performed on a sampling basis and requiring service or other environment may reference the associated development specification.

Eliminate "how-to" information from process specifications, leave the methodology to the selection of the subcontractor. Whenever possible, reference broader NASA documents in lieu of contractor process fabrication.

A contractor process specification is required only when the customer specification covering the applicable requirements is not detailed enough for the required process control. The process specification is essentially a general specification; it is, therefore, applicable only to the extent specified on the design drawing or in the equipment specification. Manufacturing or process specifications should not be referenced to the point of inhibiting manufacturing technology or initiative. By imposing detailed specifications on sellers, for instance, the seller may be forced to depart from his normal methods with no actual improvement in the end result. The emphasis always should be on design conformance, not methodology, keeping in mind that the purpose of a drawing upon which the process specification is referenced is not to control production; rather, it is to control the design configuration and to present the criteria for determining whether the item conforms to the stated requirements.

Restrict the content of Preinstallation (Bench) Test Specifications wherever possible to functional electrical and mechanical checkout instead of duplicating acceptance tests. This practice will reduce actual test time as well as specification preparation and maintenance time.

Request the subcontractor to propose Verification (Test) Methods appropriate to the type of equipment instaed of specifying them to him in detail. This procedure, particularly in the DTC environment, has several advantages. It enables the seller to exercise his initiative, and it provides alternatives for the buyer when dealing with several sellers in a competitive environment.

Encourage the reduction of testing, assessment, and analysis when advantage can be taken of previous work of a similar nature.

Eliminate or greatly reduce, whenever feasible, general requirements or specifications for such things as Human Factors, Safety, Reliability, Maintainability, etc. Instead, substitute broader functional requirements that give the seller flexibility in demonstrating that he meets them. This approach will also reduce specification maintenance cost.

A general specification covers requirements common to two or more types, classes, grades, or styles of products, services, or materials. It avoids repetition of common requirements in other specifications. It also permits changes to common requirements to be readily effected. General specifications may also be used to cover common requirements for weapon systems and subsystems, such as reliability, maintainability, human factors, weight control programs, etc, as well as sealing, watertightness, and certain finish requirements.

One of the most important things to remember about general specifications imposed on sellers is that the temptation to re-organize the seller's house must be resisted. In most cases, the sellers are capable of complying with general requirements imposed on them. As a rule, it is far more economical to be general enough to enable the seller to use his own detailed organizational setups and methods as long as he meets the end requirements. To require the seller to do everything the buyers way can be phenomenally costly. In addition, the use of general specifications require extreme care in the following areas:

• Whenever reference is made to general specifications in equipment or other specifications, such reference should be made by specific paragraph number. Theoretically, it is true that if you say "welding shall be in accordance with SPG024", it is intended that the seller comply with whatever paragraph of that specification deals with welding. He usually suspects, however, that the welding requirements may be scattered (and, unfortunately, he is usually right). Thus, he hangs a high price tag on the item to cover the requirements that he hasn't found yet. Obviously, requirements traceability is greatly aided by referencing specific paragraph numbers.

• Unless general specifications are carefully written, it becomes difficult to separate a technical task from its associated data task. If for some reason the two tasks are not properly separated, a downstream economy measure to, say, eliminate the data requirement may result in elimination of both tasks without intending to do so, For instance, a general reliability specification may contain a paragraph with the heading "3.2.1 Failure Analysis Report". If both technical and the associated data requirements are stated in this paragraph, elimination of the report requirement from the purchase order would automatically eliminate the technical task of conducting failure analysis as well as the report. To avoid this problem, the two requirements must be separated as follows:

"3.2.1 Failure Analysis"

"3.2.2 Failure Analysis Report.

3.10 CUSTOMER APPROVAL LEVELS

The following discussion of the appropriate level of approval of specifications follows in general, the arguments advanced previously relative to kinds of specifications. Recognizing that the degree of customer involvement in the affairs of a contractor is related to the degree of risk that the Government can accept, we do not advocate reduction of Government cognizance over areas in which his interest is involved. Rather, our recommendations deal with the review and approval of specification requirements which are a level below those which protect the Government's interest.

The specifications at the subsystem level contain all of the performance requirements necessary for Government approval; the Government will accept or reject the contractor's delivered items on this basis. There is little to be gained by Government approval of specifications below this level. Surveillance and visibility can still be retained, but the time-delaying repetitive effort in reviewing and approving iterating requirements allocated to these lower levels can be eliminated. Government participation in activities such as the contractor's configuration reviews and audits of his sellers can provide a more meaningful barometer of design progress and requirements compliance.

Limit customer approval to system/subsystem level, with contractor control on the black-box (equipment) specification level. This will provide greater flexibility and timeliness in contractor-subcontractor relations, and will contribute to lower costs. System and subsystem level specifications should contain only top-level performance and interface requirements; lower tier documents are selectively more detailed.

3.11 BASELINES AND CONFIGURATION CONTROL

Our recommended approach for the EOS program is addresses configuration baselining and configuration control. For optimum baseline, the recommendations for the establishment of the product baseline are: Select the point in the program for establishment of the product baseline, at or near the point of design stabilization to avoid an unnecessary and burdensome change mill. Dependent upon overall program schedule, portions of the system should be baselined independently at an optimum point for that segment.

Since the program schedule itself is the prime cost driver in the change control process, the program must be properly paced with regard to development effort and design stabilization. This will be done by the System Integrator.

The System Integrator team will review, discuss and expedite change processing. The team will screen potential changes prior to the commitment of them to proposal preparation to determine if the contractor should proceed with further effort. Conference calls between NASA/Goddard and EOS contractor program managers, with supporting personnel in attendance at either end of the conversation, can be ulitized to minimize travel and expedite change action.

While rigorous documentation of changes is necessary, we believe that an Engineering Change Proposal format that is the same as the paperwork used internally for change processing can be utilized by the NASA. This format will be specifically tailored to the EOS program and mutually agreed upon.

In the DTC environment, the System Integrator will find changes which reduce cost to counterbalance proposed changes which increase cost. Cost versus performance and requirement tradeoffs will be made continuously throughout the program.

Mutual confidence results from the identification and visibility of, and prompt solution to, problems. NASA/Goddard knowledge that the contractor is not hiding problems, rather, his is solving them, as evidenced in the S. I. recommendations, will enhance this confidence and make excessive documentation and controls unnecessary.

3.12 MAINTENANCE OF COMMONALITY

One of the objectives of our study has been to provide a General Purpose Spacecraft which can accommodate a variety of follow-on missions. This philosophy is carried through to all aspects of the recommended hardware design, management approach, procurement plan and test philosophy.

The Basic Spacecraft design is flexible enough to support the LRM, Marine Resources, Ocean Dynamics, Weather Observation and Transient Environmental phenomena. The recommended management approach provides a concept of a Systems Integrator which maintains a nucleus of people supplemented by the various team elements dependent on the emphasis of integration difficulty. The Basic Spacecraft contractor participation on the System Integration team assures the continuity of experience, test, and checkout procedures and techniques, GSE, from mission to mission.

Our recommended procurement plan coupled with our test philosophy is designed to provide for maintenance of commonality as well as incorporation of technology advances without destroying commonality and interchangeability of the Basic Spacecraft approach. The procurement plan essentially is designed to make the Basic Spacecraft a "MIL STD" part, with first procurements involving the Basic Spacecraft design development, and standard set of specifications for the EOS A and A' mission. Once the Basic Spacecraft design is qualified and proven, the Government then has a Basic Spacecraft with proven capability, and can then proceed to procure an inventory of spacecraft as funding becomes available. Our test philosophy of qualifying at the component level, qualifying the Basic Spacecraft to design limits, and acceptance testing of the Basic Spacecraft and modules separately, allows technology changes to be incorporated, and out of production components or piece parts to be incorporated within the "MIL STD" module specification with no total Basic Spacecraft impact of equal requirements.

Our recommendation, therefore, is to select a design, management approach, procurement plan, and test philosophy which in themselves support the basic objective of maintaining commonality to reduce the cost of future spacecraft programs.

4 - MANAGEMENT APPROACH ALTERNATIVES

4.1 CONTRACTING TECHNIQUES BETWEEN THE GOVERNMENT AND THE PRIME CONTRACTOR

To compare the alternate contracting techniques for the EOS program, the major elements of the program are identified as follows:

Instruments, Basic Spacecraft, Mission Peculiar Spacecraft, Control Center and Mission Controls, Central Data Processing Facility, Low Cost Ground Station, Launch Vehicle, Shroud, FSS, MEMS and the Data Acquisition Station.

These elements may be procured either individually or by a single procurement and several alternates are discussed. For the purpose of presenting these alternatives, the Launch Vehicle, Shroud, FSS, MEMS and the Data Acquisition Station are deleted, as they tend to be procurements uniquely handled by the Government.

The first alternative is for NASA/Goddard to procure, through a single procurement, the elements shown below:

Instruments
Basic Spacecraft
Mission Peculiar Spacecraft
Control Center & Mission Controls
Central Data Processing Facility
Low Cost Ground Station

This approach is preferable for systems development as the responsibility for the total program rests with a single contractor. A single procurement reduces the cost incurred by the Government and Industry for the competition and administration of the contract. As each procurement has an associated cost incurred by the Government and the contractors, the cost associated with a procurement is minimum in this approach.

The highest risk element in the EOS program is the Instruments which require development. For the System Integrator to contractually assume the contractual and techni-

cal risk associated with this procurement would add around 30% to the procurement costs of the Instruments.

Therefore a second alternative is for the Government to contract directly for the EOS Instruments and supply them to the System Integrator as GFE with the System Integrator procuring the remaining elements.

NASA/Goddard

INSTRUMENTS

SYSTEM INTEGRATOR

Thermal Mapper

Basic Spacecraft

HRPI

Mission Peculiar Spacecraft

PMMR

Control Center & Mission Controls

SAR

Central Data Processing Facility

SEOS

Low Cost Ground Station

Solar Maximum

Data Collection System

SEASAT

MSS

This approach separates the high risk elements and distributes the risk between the Government and the Contractor. The 30% increase in Instrument cost associated with this risk in our first alternative is eliminated.

As this approach increases the number of procurements, those costs associated with the procurement and contract administration are increased. As this cost involves Government cost and Contractor cost, the value is not easily determined but it could be as little as 5% or as much as 20%. In any event it appears to present a lower cost program than the first alternative.

A third alternative has Goddard procuring the Basic Spacecraft, Control Center and Mission Control with a single procurement and supplied to the System Integrator as GFE.

NASA/Goddard

SYSTEM INTEGRATOR

Basic Spacecraft

Instruments

Control Center &

Central Data Processing Facility

Mission Control

Low Cost Ground Station

Mission Peculiar Spacecraft

This approach has the advantage of developing the Basic Spacecraft early if funds are not available for total program funding. The System Integrator has the Instruments as a cost driver which will increase their cost by around 30%. The multiple procurement will also add 5% to 20% to the Basic Spacecraft.

The fourth alternative is to procure the Central Data Processing Facility and Low Cost Ground Station separate from the System Integrator effort as follows:

NASA/Goddard

SYSTEM INTEGRATOR

Central Data Processing Facility

Low Cost Ground Station

Instruments

Basic Spacecraft

Mission Peculiar Spacecraft

Control Center & Mission Controls

The system responsibility for the Spacecraft and Instruments rests with a single contractor and is beneficial for Satellite development; however, the increased costs for the Instrument risks and the multiple procurement is about the same as for alternate three.

The fifth alternative is to have three procurements as follows:

NASA/Goddard

SYSTEM INTEGRATOR

Instruments

Basic Spacecraft

Central Data Processing

Mission Peculiar Spacecraft

Facility

Control Center & Mission Control

Low Cost Ground Station

This approach groups like procurements together and isolates the high risk and low risks elements of the program. If 5% of the procurement costs is valid for multiple procurements, this approach may be the lowest cost approach. However, if procurement related costs, contract administration and interface costs are 10% or more, this approach could well be the most expensive.

As the costs of multiple contracts are not accurately predicted since no good data is available, this comparison is not exact; however, it is believed that they are within reasonable tolerances and valid for a comparison of the above alternates. Therefore from a cost viewpoint, the second alternate appears to be the most favorable for the EOS Program.

4.2 CONTRACT TYPES

The contract types available are: Cost Type, Fixed Price and Time and Material or Labor Type contracts. The cost type may have a fixed fee, incentive fee, award fee or some combination. Fixed price contracts may be firm fixed price or fixed price incentive. Other variations are available but add little to this discussion. Some concerns in selecting contract type are; whether the procurement fits the contract type, will the contract type achieve the desired results and will the administration be excessive.

The possibilities of either cost type or fixed price for the design and development and follow on is shown on Table 4-1. These initial possibilities are based on the technical advancement of each element and follow-on procurement after development.

The cost type fixed fee contract has only normal administrative problems and is simple but has not been accepted as a cost effective method.

INSTRUMENT/EQUIPMENT/ CPFF **FUNCTIONAL GROUP** CPIF CPIF/AF FPI FP T&M THERMAL MAPPER Х Х Х HRPI х Х х **PMMR** х Х х SAR Х х Х SEOS X х X SOLAR MAXIMUM х Х X DATA COLLECTION SYSTEM Х Х **SEASAT** х х х х BASIC SPACECRAFT & MODULES Х х х O O CONTROL CENTER Х X х MISSION CONTROL ΧO MISSION PECULIAR SPACECRAFT х х Χ CENTRAL DATA PROCESSING FACILITY х X × LOW COST GROUND STATION X х X O 0

Table 4-1 Contract Types

KEY:

X D&D PHASE O FOLLOW-ON

4T-3

The incentive contracts are aimed at adding incentives to the contractor. It may or may not add incentive to the project people or it may cause program perturbations that are not good for the overall program. The award fee adds some direct incentive to the project people but also may be counterproductive because of its subjective nature. Administration may be quite high.

Cost Incentives which are applicable to the EOS, System Integrator approach cover three areas; the total program, the development phase and the production phase. An incentive may be provided for the system integration effort and a separate incentive for the basic system development. An incentive program which would add emphasis to the production phase of the basic spacecraft and modules is to establish a design-to-cost goal for the production unit. The design-to-cost target would be used during the development stage and the performance would be measured by the cost of the production units.

In the selection of incentives, the potential trade-offs which may be required during the development must be considered in order that the incentive gains or losses do not jeopardize the trade-off considered.

4.3 SUBCONTRACT MANAGEMENT TECHNIQUES

The basic and alternative techniques for subcontracting are shown on Table 4-2 with the recommended approach printed in italics.

SUBCONTRACTING TECHNIQUES FOR THE ECS MODULES

The alternate methods of modular development are addressed for the development phase and production phase. The development may be done by the prime contractor from seller components and inhouse components or by the component supplier who has the bulk of the module hardware having systems responsibility.

From data received for the EOS, ACS module, the approximate cost of Systems procurement is \$7,500,000 if procured as a new system. If the Systems Engineering and fabrication is done at the prime contractor, costs are about \$6,500,000.

In this instance a further reduction of approximately \$1,000,000 in cost resulted from selecting alternate components which meet the EOS performance requirements for a lesser cost. The advantage is in being able to select components from a wide range of suppliers and performing the design, integration and test by the prime contractor.

In the production of the ACS modules for the EOS the recurring cost is about the same for either prime contractor or subcontractor production.

The development by the prime contractor, using state of the art components, has a further advantage of focusing the development cost of modules in a single source, thereby gaining maximum use of experience and techniques required for the development of modules.

For the EOS program, consideration should be given to singular module development early in the program if funding is not available for Basic Spacecraft development.

Table 4-2 EOS Subcontract Management Techniques

SUBJECT	BASIC TECHNIQUES	ALTERNATE TECHNIQUES
(1) SUBSYSTEM & COMPONENT PROCUREMENT/SYSTEM ENGINEERING	 UNDER THE PRESSURE OF INITIAL SCHEDULE PLANNING, PROCUREMENT IS OFTEN INITIATED PRIOR TO FINALIZATION OF SYSTEM DESIGN 	DELAY KEY HIGH RISK PROCUREMENTS UNTIL SYSTEM DESIGN PROVIDES CLEAR ASSESSMENT OF SUBSYSTEM & COMPONENT REQUIREMENTS
		IN CRITICAL AREAS OF SUBSYSTEM AND COMPONENT DEVELOPMENT LOCATE SELLER PERSONNEL AT GRUMMAN TO PARTICIPATE IN ESTABLISHING REQUIREMENTS
(2) CONTRACT TYPE	 WHERE DEVELOPMENT IS REQUIRED FLEXIBLE TYPE CONTRACTING IS USED FOR THE ENTIRE 	ISOLATE AREAS OF DEVELOPMENT RISK & RESTRICT FLEXIBLE CONTRACTING TO THOSE AREAS
	PROCUREMENT "PACKAGE"	IF NECESSARY DELAY FINAL PRICING OF PRODUCTION EQUIPMENT UNTIL DEVELOPMENT PROVIDES CLEAR DEFINITION FOR FIXED PRICE CONTRACTING
(3) PRODUCTION RELEASE	 DUE TO SCHEDULE DEMANDS SUBCONTRACT PLANNING OFTEN REFLECTS COMMITMENT OF RESOURCES TO MANUFACTURE OF PRODUCTION EQUIPMENT PRIOR TO COMPLETION OF DESIGN & QUALIFICATION 	COMPLETE QUALIFICATION TESTING & PRODUCEABILITY REVIEWS PRIOR TO PRODUCTION RELEASE
(4) SPECIFICATION FORMAT	 PROCUREMENT SPECIFICATIONS CONTAIN HIGH DEGREE OF DESIGN DETAIL 	PROCUREMENT SPECIFICATION WILL CLEARLY DEFINE CRITICAL INTERFACE PARAMETERS & PERFORMANCE CRITERIA ESSENTIAL TO TOTAL SYSTEM PERFORMANCE & MINIMIZE RESTRICTIVE DESIGN
(5) HARDWARE ACCEPTANCE	 HARDWARE ACCEPTANCE BASED UPON INSPECTION & TEST UNIT AT SOURCE &/OR DESTINATION 	ACCEPTANCE OF HARDWARE BASED UPON SUCCESSFUL INSTALLATION & TEST IN SPACECRAFT
		• FUND SELLER PERSONNEL TO PARTICIPATE IN INSTAL- LATION & SPACECRAFT CHECKOUT
(6) FEE INCENTIVES	 INCENTIVES WHERE USED NORMALLY APPLIED TO COST, SCHEDULE &/OR FACTORY TESTING 	PROVIDES INCENTIVE BASED UPON PERFORMANCE OF EQUIPMENT IN ORBIT
(7) PRODUCEABILITY	NO CLEAR PRODUCEABILITY REQUIREMENTS DURING DESIGN & QUALIFICATION PHASE	ASSIGN PRODUCEABILITY PERSONNEL TO PARTICIPATE IN EARLY DESIGN REVIEWS (BOTH SELLER & BUYER PERSONNEL)
(8) OPTION PRICING	 NEGOTIATE FOLLOW-ON PRODUCTION AS NEW PROCUREMENTS 	INCLUDE IN INITIAL PROCUREMENT OPTION PRICES FOR FOLLOW-ON REQUIREMENTS
(9) DATA REQUIREMENTS	 PROCURE DATA IN ACCORDANCE WITH UNIFORM STANDARD REQUIREMENTS 	TAILOR DATA REQUIREMENTS TO EACH PROCUREMENT
		DEFINE DATA REQUIREMENTS IN TERMS OF USER REQUIREMENTS
		USE EXISTING DATA IN SELLER FORMAT WHERE POSSIBLE
(10) QUALITY ASSURANCE	 SURVEILLANCE OF SELLER CONDUCTED BY BOTH GRUMMAN & GOVERNMENT AGENCY 	GRUMMAN ASSUMES TOTAL RESPONSIBILITY FOR SURVEILLANCE OF ITS SELLERS
(11) PAYMENTS	 SELLERS SEEKING FINANCIAL RELIEF UNDER FIXED PRICE CONTRACTING NORMALLY RECEIVE PROGRESS PAYMENTS 	PROVIDE MILESTONE PAYMENTS BASED UPON MEASURABLE COMPLETION OF KEY TASKS
(12) APPROVAL OF SUBCONTRACTS	 PRIME CONTRACT DOES NOT SPECIFY TIME LIMITATION ON APPROVAL CYCLE 	PROVIDE LIMIT OF 10 DAYS FOR APPROVING PLACE- MENT OF SUBCONTRACTS
(13) PROCUREMENT OF CRITICAL COMPONENTS	 EACH SELLER BUYS SEPARATELY EVEN THOUGH CRITICAL COMPONENTS MAY BE COMMON TO SEVERAL EQUIPMENTS 	SELECTIVELY IDENTIFY COMMON HIGH RELIABILITY, COMMON COMPONENTS & HAVE GRUMMAN PURCHASE TO FURNISH CFE TO SELLERS
(14) QUALIFICATION UNITS	 DELIVERED AS RESIDUAL MATERIAL AT CON- TRACT COMPLETION 	SELECTIVELY IDENTIFY UNITS FOR REFURBISHMENT FOR FLIGHT USE
(15) RISK ANALYSIS	COST, SCHEDULE, AND TECHNICAL RISK ARE CO-MINGLED WITH OTHER FACTORS IN THE PRE-AWARD EVALUATION	PROVIDE SEPARATE SCHEDULE, COST & TECHNICAL RISK ANALYSIS INDEPENDENT OF OTHER FACTORS, TO BE USED AS A SELECTION CRITERIA & A BASIS FOR PROGRAM PLANNING
(16) GOVERNMENT FURNISHED EQUIPMENT & SERVICES	GFE LIST DEFINED AND PROVIDED IN PRIME CONTRACT	CONSIDER GOVERNMENT AS POTENTIAL SUPPLIER IN SOURCE SELECTION PROCESS FOR SUCH ITEMS AS SPECIAL TEST EQUIPMENT, RESIDUAL FLIGHT HARDWARE, ENGINEERING SERVICES & TEST FACILITIES & SERVICES DURING THE LIFE OF THE CONTRACT
(17) CHANGES	ORDERED ON "FLY NOW, PAY LATER" BASIS	 FIRM SUBCONTRACTOR COMMITMENTS MADE KNOWN TO PROGRAM CCB BEFORE DECISION MADE TO PROCEED

4.4 RELIABILITY AND QUALITY ASSURANCE

RELIABILITY - The NHB5300-4 is used as a basis for comparison for alternate approaches appropriate for the EOS Program.

The Reliability tasks listed in NHB5300.4 (1A) have been reviewed to identify those tasks which can be performed in a more cost effective manner without altering program risks. The three major areas investigated are:

Reliability Program Management Reliability Engineering Test and Reliability Evaluation

For these three areas all subtasks have been listed, the normal approach to fulfilling the requirement briefly described, and any viable EOS alternatives with appropriate Rejection/Selection criteria discussed. The approach (normal or EOS alternative) selected for EOS has been printed in italics in Table 4-3.

If all the alternatives blocked out are selected, an estimated 7200 man hours savings can be realized without altering program risk.

QUALITY ASSURANCE - Alternates recommended to replace the requirements of NHB-5300 5300-4 (1B), are printed in italics in Table 4-4.

Quality Assurance Program Development - Procurement quality control requirements will be "custom tailored" to the complexity cost of the subcontracted equipment.

Subcontractors for major subsystems will be required to follow the requirements of QES-0001, "Quality Control Requirements for Major Subsystems". In addition, all other suppliers of materials, parts, and components will be required to follow QEC-002, "Seller Quality Control Requirements".

Three levels of Quality Assurance Control will be established for equipment procured for the EOS program. The most stringent level is imposed on new design hardware, a less stringent level is imposed on Modified Off the Shelf Hardware, and the least stringent level is imposed On the Shelf Hardware. Requirements for these levels of control will be tailored and extracted from QES-0001 and QES-0002 or from any contractor document for Quality Assurance.

Table 4-3 Reliability Issues (Sheet 1 of 3)

TASK	NORMAL	EOS ALTERNATIVES	REJECTION/SELECTION CRITERIA
RELIABILITY PROGRAM MANAGEMENT			
1A201 RELIABILITY PROGRAM PLAN	PLAN DESCRIBES ACTIVITIES TO ENSURE COMPLIANCE WITH SPECIFIED REQUIREMENTS - UPDATED PERIODICALLY - SEPARATE SITE PLANS	A. DELETE PLAN	A. THIS WAS REJECTED SINCE A PLAN SIGNED BY THE GRUMMAN PROGRAM MANAGER IS REQUIRED TO AUTHORIZE, CONTROL, & ORGANIZE ALL ELEMENTS OF THE RELIABILITY PROGRAM
		B. DELETE FORMAL PLAN REQUIRING NASA APPROVAL	B. WITHOUT APPROVAL NASA LOSES CONTROL OVER RELIABILITY EFFORTS
		C. DELETE PERIODIC UPDATE. UP- DATE ONLY AS REQUIRED	C. UPDATE OF PLAN SHOULD BE UPDATED AS REQUIRED FOR MAJOR CHANGES INSTEAD OF PERIODICALLY
		D. SITE PLANS SHOULD BE INCORPORA- TED IN BASIC PLAN	D. WOULD ELIMINATE SEPARATE DOC WITH ADDITIONAL SUBMISSION & APPROVAL CYCLES WITH NO LOSS IN INFORMATION
1A202 RELIABILITY PROGRAM CONTROL	CONDUCT REGULARLY SCHEDULED PROGRAM REVIEWS & SUBMIT RE-	A. DELETE FORMAL REVIEW & CONTINUE REPORT AND DAILY TELECON	A. SIGNIFICANT PROBLEMS MAY REQUIRE FORMAL REVIEW
·	GULARLY SCHEDULED FORMAL WRITTEN PROGRESS REPORTS. RE- PORT DAILY BY TELEPHONE	B. DELETE WRITTEN REPORT & CONTINUE REVIEWS AND DAILY TELECON	B. REPORTS REQUIRED TO DOCUMENT RE- SULTS & ASSIGN ACTIONS
		C. CONDUCT FORMAL REVIEW ONLY WHEN SIGNIFICANT PROBLEMS OCCUR. CONTINUE DAILY TELECON. NO FORMAL REPORTS	C. ALLOWS DETAILED REVIEW & CONCEN- TRATED EFFORT ON PROBLEM AREAS AS REQUIRED. HOWEVER, RESULTS SHOULD REQUIRE REPORT
		D. CONDUCT FORMAL REVIEWS ONLY AT MAJOR PROGRAM MILESTONES. NO FORMAL REPORTING, CONTINUE DAILY TELECON	D. DOES NOT ALLOW FOR REVIEW IF SIGNIFI- CANT PROBLEMS ARISE. RESULTS NOT DOCUMENTED
		E. INTEGRATE WITH DESIGN REVIEW & CONDUCT ADDITIONAL REVIEWS ONLY WHEN SIGNIFICANT PROBLEMS OCCUR	E. ALLOWS ADEQUATE REVIEW & AUDIT OF RELIABILITY PROGRESS & IS COORDINATED WITH OTHER PROGRAM EFFORTS. FLEXIBLE IN THAT SIGNIFICANT PROBLEMS CAN BE ADEQUATELY RESEARCHED, REVIEWED & SPECIFIC ACTION ITEMS GENERATED
1A203 RELIABILITY PROGRESS REPORTING	REPORT PERIODICALLY ON THE PRO-	A. DELETE FORMAL REPORTING	A. WITHOUT REPORTS RESULTS NOT DOCU- MENTED & ACTION NOT ASSIGNED
	PROGRAM - WRITTEN PROGRESS REPORTS - RELIABILITY PROGRAM CONTROL REPORTS	B. LIMIT FORMAL REPORTING TO SIGNI- FICANT EVENTS & PROBLEM AREAS	B. WILL GIVE THE REQUIRED VISIBILITY TO NASA ON MAJOR EVENTS WITHOUT TECH- NICAL COMPROMISE
1A204 RELIABILITY TRAINING	PROVIDE TRAINING & INDOCTRINA- TION IN TECHNOLOGIES & TECHNIQUE PECULIAR TO THE PROGRAM	A. DELETE FORMAL TRAINING	A. GRUMMAN WILL APPLY ITS FIFTEEN YEARS OF SUCCESSFUL SPACE RELIABILITY PRO- GRAM EXPERIENCE TO PLAN & CONDUCT AN EFFECTIVE RELIABILITY PROGRAM FOR EOS
1A205 SUPPLIER CONTROL	ENSURE THAT THE RELIABILITY OF SYSTEM ELEMENTS OBTAINED FROM SUBCONTRACTORS & SUPPLIERS MEETS THE RELIABILITY REQUIRE- MENT OF THE OVERALL SYSTEM	,	,

Table 4-3 Reliability Issues (Sheet 2 of 3)

TASK	NORMAL	EOS ALTERNATIVES	REJECTION/SELECTION CRITERIA
RELIABILITY PROGRAM MANAGEMENT (CONT)			
1A206 RELIABILITY OF GFE	IDENTIFY RELIABILITY DATA NEEDED ON GFE & WHERE DATA SHOWS INCON- SISTENCY OF THE GFE WITH RELIA- BILITY. REQUIREMENTS OF OVER- ALL SYSTEM, NASA SHALL BE FOR- MALLY AND PROMPTLY NOTIFIED		
RELIABILITY ENGINEERING			
1A301 DESIGN SPECIFICATIONS	GENERATE A DESIGN SPEC FOR EACH ITEM OF HARDWARE AT THE SYSTEM, SUBSYSTEM AND COMPONENT LEVEL		
1A302 RELIABILITY PREDICTIONS	DEVELOP RELIABILITY PRODICTION MODELS AND PREDICTIONS FOR THE SYSTEM	A. DELETE ALL PREDICTIONS	A. UNDESIRABLE SINCE CANNOT PERFORM TRADE STUDIES, MAINTAINABILITY ANALYSES AND LOGISTICS PLANNING
	UPDATED BY DESIGN EVOLUTION MODELED DOWN TO THE COM- PONENT LEVEL	B. PERFORM PREDICTIONS TO THE EX- TENT NECESSARY TO SUPPORT — TRADE STUDIES — MAINTAINABILITY ANALYSES — LOGISTICS PLANNING DO NOT UPDATE MINOR DESIGN CHANGES OR GENERATE COMPLEX MODELS INTERNAL TO BLACK BOXES	B. GENERATING PREDICTIONS TO VERY DE- TAILED LEVELS AND GENERATING COM- PLEX MODELS INTERNAL TO BLACK BOXES IS EXPENSIVE AND OF QUESTION- ABLE VALUE. PREDICTIONS SHOULD BE TO SUFFICIENT LEVELS TO SUPPORT CON- FIGURATIONS TRADES, REDUNDANCY ALLOCATIONS, REL/COST STUDIES, M ANALYSES, SPARES AND LOGISTICS PLANNING ONLY
1A303 FAILURE MODE, EFFECT, & CRITICALLY ANALYSIS	PROVIDE DETAILED FMEA'S AT THE SYSTEM, SUBSYSTEM AND COM- PONENT LEVELS	A. DELETE REQUIREMENT FOR PROBLEM OF OCCURENCE FOR ALL BUT SINGLE POINT FAILURES	A. PROBABILITY OF OCCURANCE IS OF LIMITED PRACTICAL VALUE AND IN- VOLVES SIGNIFICANT ENGINEERING EFFORT
		B. PERFORM FMEA'S WITHIN A "BLACK BOX" FOR ALL CRITICAL FUNCTIONS AND TO THE PIECE PART LEVEL FOR HAZARDOUS AND MISSION SUCCESS CRITICALITY FAILURES ONLY	B. DETAILED FMEA'S WITHIN A BLACK BOX ARE EXPENSIVE AND UNNECESSARY FOR BOXES, WHICH, IF THEY FAIL, DO NOT IMPACT MISSION SUCCESS OR PERSONNEL SAFETY
		C. DO NOT SUBMIT FORMAL REPORT. KEEP WORKSHEETS FOR DOCUMEN- TATION	C. MANY WORKSHEETS REQUIRE REPORT TO SUMMARIZE, FORM CONCLUSIONS AND MAKE RECOMMENDATIONS
	·	D. LIMIT REPORT TO A LIST OF SFP'S	D. LOSS OF VISIBILITY WITH LITTLE OR NO REAL SAVINGS
1A306 PROBLEM/FAILURE REPORTING &		D. DELETE GSE FROM FAILURE RE- PORTING SYSTEM	D. THIS WILL SEVERELY IMPACT THE RELIA- BILITY OF LAUNCH CRITICAL GSE
CORRECTION		E. INCLUDE LAUNCH CRITICAL GSE (USED IN LAST 72 HR PRIOR TO LAUNCH) IN FAILURE REPORTING SYSTEM & OTHER GSE ONLY AS REQUIRED	E. THIS WILL MAINTAIN THE HIGH RELIABIL ITY REQUIREMENTS FOR LAUNCH CRITICAL GSE WHILE ALLOWING A COST EFFECTIVE APPROACH TO FAILURE CLOSE OUT TO OTHER GSE
1A307 STANDARDIZATION OF DESIGN PRACTICES	MAINTAIN AN EFFORT TO STAND- ARDIZE & CONTROL DESIGN PRACTICES & FABRICATION PROCESSES		, i

Table 4-3 Reliability Issues (Sheet 3 of 3)

TASK	NORMAL	EOS ALTERNATIVES	REJECTION/SELECTION CRITERIA
RELIABILITY ENGINEERING (CONT)			
1A308 PARTS, DEVICES & MATERIALS PROGRAMS	IMPLEMENT A PROGRAM COVERING SELECTION, REDUCTION IN NUMBER OF TYPES, SPECIFICATION APPLICA- TION REVIEW, ANALYZING FAILURES, STOCKING & HANDLING METHODS, ESTABLISHING RELIABILITY REQMTS FOR ELECTRICAL & MECHANICAL PARTS		·
TESTING AND RELIABILITY EVALUATION			
1A401 RELIABILITY EVALUATION PLAN	AS A SEPARATE SECTION OF OR SUB- SIDIARY DOCUMENT TO THE RELIA- BILITY PROGRAM PLAN, THE CON- TRACTOR SHALL SUBMIT A PLAN OF THE RELIABILITY EVALUATION PROGRAM		
1A402 TESTING	COMPONENT QUALIFICATION — SIMULATE CONDITIONS WHICH ARE MORE SEVERE THAN GROUND, LAUNCH AND ORBITAL CONDITIONS IN ORDER TO LOCATE DESIGN DEFICIENCIES	SAME AS A NORMAL EXCEPT ELIMINATE HUMIDITY TESTING ON QUALIFICATION UNITS SAME AS NORMAL EXCEPT SUBSTITUTE THERMAL CYCLING FOR THERMAL VACUUM TESTING FOR ALL BUT CORONA	ENVIRONMENTAL PROTECTION IS PROVIDED BY GROUND SUPPORT EQUIPMENT THERMAL VACUUM TEMPERATURE RAMPS ARE VERY SLOW, THUS THEIR USE AS EFFEC- TIVE WORKMANSHIP SCREENS FOR ALL BUT
	COMPONENT ACCEPTANCE — ENVIRON- MENTALLY TEST COMPONENTS FOR THE PURPOSE OF LOCATING LATENT MATERIAL AND WORKMANSHIP DE- FECTS IN COMPONENTS OF PROVEN DESIGN	SENSITIVE AND HIGH-POWER DEVICES	CORONA SUSCEPTIBLE EQUIPMENTS IS QUESTIONABLE. MORE EFFICIENT & COST EFFECTIVE TO USE THERMAL CYCLING TO DETECT WORKMANSHIP DEFECTS
1A403 RELIABILITY ASSESSMENT	ASSESS SYSTEM RELIABILITY AT MILESTONES SPECIFIED IN RELIA- BILITY EVALUATION PLAN		
1A404 RELIABILITY EXISTS TO READINESS REVIEW	PROVIDE ALL PERTINENT RELIA- BILITY DATA NECESSARY TO SUP- PORT EACH PROJECT MILESTONE REVIEW	-	·
1A405 RELIABILITY EVALUATION PROGRAM REVIEWS	AT APPROPRIATE MILESTONES SCHEDULED IN THE RELIABILITY PROGRAM PLAN THE CONTRACTOR SHALL REVIEW HIS RELIABILITY EVALUATION EFFORT	INTEGRATE WITH DESIGN REVIEWS & OTHER PROGRAM MILESTONES, CONDUCT ADDITIONAL REVIEWS ONLY WHEN SIGNIFICANT PROBLEMS OCCUR	ALLOWS ADEQUATE REVIEW & AUDIT OF RE- LIABILITY PROGRESS & IS COORDINATED WITH OTHER PROGRAM EFFORTS

Table 4-4 Quality Assurance Issues

NHB 5300-4 (IB) STUDY ISSUES	NORMAL APPROACH	EOS ALTERNATIVES
18102-(1) ACTIONS & PREROGATIVES OF THE GOVERNMENT	THE OPERATIONS & WORK OF THE CONTRACTOR & HIS SUPPLIERS ARE SUBJECT TO EVALUATION, REVIEW, AUDIT, SURVEY, & INSPECTION BY THE	TEST & INSPECTION VERIFICATION BY GOVERNMENT INSPECTION AGENCY TO BE ON A POST-AUDIT BASIS TO REDUCE COST & ELIMINATE DELAY.
	PROCURING NASA INSTALLATION & ITS DESIGNATED GOVERNMENT QUALITY REPRESENTATIVE	POST-AUDIT PERMITS GRUMMAN TO MOVE AHEAD IN THE MANUFACTURING/TEST CYCLE WITH MONITORING BY GOVERNMENT REPRESENTATIVE
18706-(2)* INSPECTION & TEST RECORDS	REQUIRES DOCUMENTATION OF CONTINUOUS HISTORY OF EQUIPMENT BY UPDATING EACH SYSTEM & SUBSYSTEM RECORD	DETERMINE TRACEABILITY REQUIREMENT ON BASIS OF NEED. DISTINGUISH BETWEEN: • CRITICAL STRUCTURAL ITEMS • LIMITED LIFE/CYCLE ITEMS • MATCHED ITEMS REQUIRING REPLACEMENT IN PAIRS • ROUTINE, LESS COMPLEX ITEMS
18804-{1} MATERIAL REVIEW BOARD	REQUIRES ESTABLISHMENT OF A THREE MEMBER BOARD FOR DISPOSITIONING NON-CONFORMANCES	INTRODUCE A SIMPLIFIED MATERIAL REVIEW SYSTEM TAILORED TO THE SIGNIFICANCE OF DEFECT & ITEM CRITICALITY. DELEGATE RESPONSIBILITY TO A SINGLE (ENGINEERING) AUTHORITY. OUALITY ASSURANCE WILL IMPLEMENT CORRECTIVE ACTION. GOVERNMENT REPRESENTATIVE WILL EXERCISE JURISDICTION ON POST-AUDIT BASIS
1B30Z-(2) CHANGE CONTROL	SPECIFY THE EFFECTIVITY POINT OF DOCUMENTS & CHANGES WHICH AFFECT MATERIALS, FABRICATION, OR PERFORMANCE	ASSURE TIMELY DISTRIBUTION OF WORKING PROCEDURES & MONITOR BY QUALITY ASSURANCE AUDITS
1B604 WORKMANSHIP STANDARDS	REQUIRES STANDARDS TO BE JOINTLY SELECTED BY NASA & GRUMMAN	GRUMMAN WILL SELECT STANDARDS. STANDARDS WILL BE SUBJECT TO CONTINUING NASA REIVEW

4T-6

4.5 TESTING PHILOSOPHY

Study Alternatives

The trade studies performed in support of the selection of the recommended approach are documented in Report No. 3, Subsection 6.18.2.

4.6 DOCUMENTATION AND CONTROLS

In the course of the EOS System definition study, Grumman has examined alternative low cost management techniques in the area of documentation and controls. Our basic goal in this study is to recommend approaches that can provide NASA with visibility of EOS development progress during Phases C and D and enhance mutual confidence without excessive documentation and control. The recommendations in this section, if implemented, will provide NASA with all of the basic information it needs to measure and guide Program performance, while simplifying and reducing the corollary cost of documentation review, ordering, delivery, storage and retrieval, specification requirements, configuration baselining and change control.

STUDY APPROACH - Everyone "knows" that data/documentation and management control costs are high. No-one has yet been able to realistically determine a workable method for evaluating the cost effectiveness of a given item of documentation in the face of its "champion" claiming that he absolutely had to have it. Moreover there are few in Government or industry who can stand up to the challenge that lack of a given item of data could result in eatastrophic loss of an aircraft or spacecraft worth millions of dollars.

How then does one approach the generation of a set of recommendations to a government agency for reductions to documentation and control costs? After due deliberation, we decided to approach the subject in a frontal manner. We asked ourselves the following questions:

- What are applicable documentation and control costs and why are they so high?
- How are the requirements for documentation and controls established? What could be done by NASA, and by contractors, to arrest the proliferation of documentation?
- What practical changes to typical documentation and control requirements could be made to minimize cost without impact to essential program control and visibility?

We applied these questions to a variety of source information related to present and past Grumman contract data requirements in many DOD and NASA contracting situations including:

- Requests for Proposal and resultant contract data/documentation requirements lists and descriptions
- Past studies on reduction of data/paperwork conducted by Grumman
- Cost reduction and value improvement proposals submitted by Grumman on several DOD Programs
- A summary of lessons learned during the NASA Lunar Module Program
- Studies conducted under the auspices of industry associations such as AOA and EIA on data reduction and data pricing
- The Harbridge House Study of Requirements for Data and Management Control Systems in Three Engineering Development Programs
- Studies conducted in-house in conjunction with specification of requirements in a design-to-cost environment.

We then evaluated the material gathered and summarized our findings in response to the questions posed above. The evaluation was done in a qualitative rather than a quantitatative framework using our best judgment as to potential savings in cost since a quantitative analysis of recommendations of this type is highly subjective and therefore suspect. We want our suggestions to be evaluated on the basis of good management sense rather than on the validity of mathematical computations or assumptions.

From these findings we formulated the specific recommendations to be made to NASA with regard to the EOS Phases C and D.

FINDINGS AND RECOMMENDATIONS - Our findings and recommendations are summarized and discussed in this section. Because of the many overlapping and inter-related areas in which they could be expressed, we have chosen to group our conclusions under the following broad categories which correspond to the subparagraphs that follow:

- Documentation Requirements
- Requirements Specification
- Baseline and Change Controls (See Subsection 4.7)

DOCUMENTATION REQUIREMENTS

Recognizing that the most effective means of reducing cost is to eliminate the requirements altogether, the first topic we addressed was the methodology of establishing the requirements for documentation in the first place under the heading:

"Requirements Establishment and Ordering Techniques"

Secondly, since we know that costs of documentation and controls are perturbed by the rigidity/flexibility of format of the documentation required to be submitted to the NASA under the contractually imposed requirements. We attacked this subject under the heading:

"Documentation Formats and Management Systems Requirements"

Finally, a significant cost driver is the processing and handling of the documentation itself by both the Contractor and NASA. We discuss this subject, which includes the submittal approval/disapproval mechanics and the appropriate levels of NASA involvement in documentation approval, under the heading:

"Documentation Processing and Review"

REQUIREMENTS ESTABLISHMENT AND ORDERING TECHNIQUES - The 'business-as-usual' method of determining the documentation required to be furnished to the Government during the course of the performance of a contract occurs in one of two (2) ways:

- The Government, in its RFP, specifies documentation requirements on a Contract Data Requirements List (CDRL), DD Form 1423 or equivalent, to which the Contractor responds in his proposal, and the Government furnishes the final list, after some negotiation, with the Contract.
- The Contractor is requested to furnish the data list in his proposal; the Government reviews it, and after negotiation, furnishes the final list with the Contract.
- In either case, documentation is required to be furnished for approval or information to a cited format, to a specific or event-related schedule, and to a given distribution list.

Several factors determine the "tailoring" of requirements to supply only the minimum "essential" information.

- There is an inherent tendency to overspecify data needs at the early stage of a program life cycle when compiling these requirements from "shopping" lists derived from previous programs. "If it was ordered before, I must need it, although I am not sure at this point, why", or "I may need this information if...."—contingency data for which the contingency may be remote and never occur.
- The Contractor is hesitant to dispute with the Government at a time when he is a candidate for a contract. Playing it safe is the general rule. DOD and NASA are as like good businessman negotiating for as much as possible for their dollar, often with several contractors simultaneously.
- After contract award, attempts to eliminate data by the Contractor meet with resistance. There is usually at least one user who can staunchly claim that he "needs" the item of documentation, and he is probably correct since he has planned his work pattern in anticipation of receiving it. Further, when eliminating documentation, it is difficult to determine the "real" cost savings
- Present methods of forecasting documentation needs in RFP's and contracting for them long before the true need for information often results in poor 'timing" of the delivery requirements and adds to the work effort without providing the user the information when he really needs it.

A conclusion that may be reached from the above is that the usual methods of establishing and ordering data, while designed to provide a methodical process giving visibility and control, do not generally inhibit documentation excess and proliferation.

The following recommendations, offered for consideration, address this area of documentation requirements establishment and ordering techniques:

Recommendation 1

Limit the documentation ordered at contract award to the unique legally (procurement regulation) mandated items, the key documents obviously required for approval by NASA and an accession list of all other data prepared by the Contractor as a by-product of his work scope.

Recommendation 2

Conduct review and "tailoring" of documentation requirements to the specific program needs after the contractor selection and before finalization of the contract when the Contractor is free from the pressure of competition and NASA is freed from the requirement to keep things equal between competitors.

A THE RESERVE

Recommendation 3

Utilize Deferred Ordering of the other information wherein the Procuring activity identifies in the contract the types of documentation by subject, not in detail, which might be ordered later, and/or Deferred Requisitioning wherein the procuring activity uses the contractor as a documentation depository, ordering copies as needed.

- (1) Adjustments in timing can be made.
- (2) Substitution of other available information better suited to the users needs perhaps can be determined.

Recommendation 4

In lieu of Requirements 1 and 2, provide a NASA/Contractor review of documentation requirements (forward looking) concurrent with technical design review process to scrub and revise the contract requirements as the program unfolds, using this approach:

- (1) Items that are "Now apparently" not needed can be eliminated.
- (2) The need for contingency items can be determined with greater accuracy.

Recommendation 5

Encourage "data minimization" by providing incentives within NASA as well as the Contractor for reduction of formal documentation in favor of other means of acquiring equivalent information.

DOCUMENTATION FORMATS AND MANAGEMENT SYSTEM REQUIREMENTS - One reason that documentation costs are typically high is the expenditure of resources to formalize reports, test data, specifications, procedures, manuals, and plans. Documentation costs are incurred both directly and indirectly. The costs directly associated with providing specified data, such as the in-house identification and validation functions, are relatively obvious. Less obvious are the costs associated with requirements to comply with the multitude of management information and control systems which may be required indirectly in order to satisfy individual data requirements. Time and resources devoted to marginally necessary systems and their attendant documentation preclude the contractor from spending them on the mainstream development effort which is the effort being monitored by the "System" in the first place.

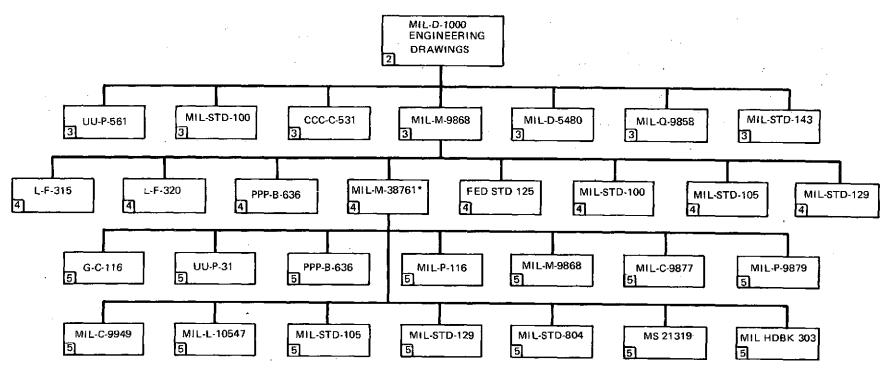
This is not to say that management controls are not needed, and that no specific data requirements should be imposed. However, the rigidity of format could be considerably

relaxed. Data requirements should reflect the minimum acceptable documentation that will supply the user with the depth and content of the information he needs. The Contractor should be able to satisfy most of the requirements with information that is a normal output of the management/design/development/production effort performed using generally good business practices. When the Government imposes management system requirements on the Contractor that force him to use formats that are not suitable for his in-house use without rearranging his standard business practices, he overlays added work scope and creates in effect two overalpping reporting systems which devour manpower.

In any Government/industry program, there is a significant amount of verbal and other informal exchange of information between Government and Contractor personnel at all levels. This less formal communication, often documented as a memo of a telephone conversation, etc., results in as many decisions, or more, perhaps than formal documentation often delayed by matters of syntax and semantics. Face-to-face verbal discussion promotes the mutual trust, respect and teamwork that is an EOS Program objective, rather than the adversary management attitude that is inherent in more formal communications.

There are a number of areas where rigid format requirements can be relaxed with no adverse effect on the contract performance, end product use, or supportability. One such area is the Engineering Drawing requirements. All DOD and NASA contracts specify detailed military drawing requirements, e.g., MIL-STD-100 and MIL-D-1000 and attendant subsidiary specifications for microfilm ability, readability, abbreviations, types of paper, and definition, as reflected in Fig. 4-1. This diagram illustrates the breakdown into subsidiary military specifications of MIL-D-1000, Engineering Drawings and Associated Lists.

Contractors and subcontractors involved in the manufacture of more sophisticated hardware today, whether for the Government use or not, find it an absolute necessity to develop a good set of drawings to good standards if their product is to be built in-house or produced in whole or in part by a subcontractor. Review of their drawings reveals that they are suitable for performing their function of communicating technical information necessary for manufacturing the product, and that they can be readily microfilmed. Whether fourth generation microfilm will be legible as required by the MIL-SPECS is a moot point. That requirement is a cost driver that should be summarily eliminated. The myriad of similar non-essential requirements, illustrated by Fig. 4-2 are typical of the factors that drive many qualified contractors away from Government-related business. It is costly but



Five or more levels of subsystem specifications and standards involved wholly or in part by citing one MIL-SPEC.

Fig. 4-1 Contract Management/Contract Configuration Management Plan

4-11

DEVELOPMENT/PRODUCT SPECIFICATIONS

necessary to maintain an overhead staff just to understand and keep abreast of the requirements. Furthermore, the format rigidity required by military formats require personnel training, changes for correction of non-technical format errors, consume added preparation and checking time, and yet add nothing of substance to the Program.

Another area loosely falling under the category of format is the storage and retrieval functions of documentation management and the media of transmittal. Today's microform technology has progressed to the point where it is highly economical to store, retrieve and transmit information in this form.

With a minimum complement of equipment available to the contractors and the procuring activity, a significant savings in storage space, reproduction time, and transmittal time can be realized. A 100 page document, for example, if stored by the contractor in microfilm form can be reproduced and put in the mail in minutes.

Many of the recommendations we are making in this section run counter to a trend that has been advocated in the DOD recently for the treatment of deliverable documentation similarly to the treatment of hardware. Those concerned with the institution of such systems as MILSCAP, for example, have attempted to institute individual data item pricing and delivery via DD-250. In addition there have been several drafts circulated to industry for review which expand the quality assurance provisions of such specifications as MIL-Q-9858, to cover data item quality.

In our judgement, these requirements are unnecessary. They add to the administrative burden of documentation, and add controls that are not cost-effective. There is little possibility that personnel assigned to perform documentation quality functions will be technically qualified to realistically evaluate the content of the documentation. Their contribution will largely regress to one of format and syntax evaluation and will delay and add to the cost of the communication of information. To require DD-250's for data items, is, in our opinion, a waste of resources that could be more productively spent.

To formalize this discussion in the form of specific recommendations, we offer the following:

Recommendation 6:

Emphasis should be placed on maximum use of Contractor format whenever it can fulfill the "intent" of the documentation or system requirement of NASA.

Recommendation 7:

Documentation requirements should take into consideration the regular review, monthly status meetings, etc. which take place as a forum for transmitting the needed information rather than via formal reports. Minutes of such meetings could supplement many 'data items'.

Recommendation 8:

Utilize informal working documentation - the same material that the Contractor's engineers used to make their decisions - in lieu of formal reports. Some examples of this information might be engineers notebooks, engineering layouts and raw data sheets. Good engineers often keep copies of their notes, but abhor report writing. Good data need not be "pretty" to do the job, and NASA personnel are technically competent to review the same data and make their conclusions in an "over-the-shoulder" or "on-the-board" environment.

Recommendation 9:

Specify Engineering Drawing requirements to industry standards rather than strict Government requirements. Examples where drawing requirements can be modified are as follows:

- Use of Engineering layouts in lieu of formal assembly and installation drawings
- Elimination of margins and zones on engineering layouts
- Eliminating rivet length callout on drawings for rivets which measure less than 1" in length.
- Less restrictive reproducibility requirements for paper copies (Reference MIL-D-5480, Para. 3.2.1)
 - allowing full legibility of first generation copies in lieu of fourth generation.

Recommendation 10:

Replace conventional hard copy transmittal of documentation, wherever practicable, with microfiche. This recommendation is particularly applicable in conjunction with the deferred ordering or accessioning of documentation.

Recommendation 11:

Do not implement requirements for more Quality Assurance imposed on documenta-

tion and do not require DD-250's (or equivalent) for documentation. The recommended direction is to reduce this type of requirement, not increase it.

DOCUMENTATION PROCESSING AND REVIEW - Every time a data item is specified as required to be furnished to the Government, a chain of data management activities is triggered. Of course, if a subcontractor is involved, the process is further complicated.

Traditionally, there are too many data items required for approval, or to state it another way, approval of documentation takes place at too low a level of detail. Approval of higher level documents which, for example, control the performance parameters of the Spacecraft, is of course required. However, lower level documentation serves NASA's surveillance role and either reinforces or diminishes its confidence in the Contractor. NASA approval or disapproval of specific items of documentation in no way abrogates the Contractor's responsibility to meet his contractual performance requirements. However, the approval process bears added administrative expense on both parties and can cause delays to events that are contingent upon the data's approval. There is no reason why documentation submitted for information cannot be used for decision-making purposes as effectively as documentation submitted for approval.

Among the areas typically overspecified in terms of approval requirements are:

- Engineering Drawings
- Non-Standard Parts
- Equipment Performance and Test Specifications, Plans and Procedures

On many contracts, contractor-prepared design concept drawings, manufacturing drawings and all changes thereto are signed by the Government's Representative before release and manufacture of parts. Even though they have signed the manufacturing drawings, the Government has not approved them but merely allowed the Contractor to release them. The Contractor is still required to meet the total requirements of the Systems Specification. During the course of a development/production program, there are always a significant number of changes to initial releases. Deleting this signature requirement from all but the design concept (layouts) would eliminate an unnecessary administrative cost. The Government Representative is in no way inhibited from exercising his surveillance function if he is on distribution of copies for information. His contribution, however, would be on a non-interference basis – exercised only when he determines that approved design concepts are being deviated from.

In the area of Non-standard parts, tube, diode and transistor complements, etc., there are too many iterations during RDT&E projects to make this documentation worth—while prior to a point of design stabilization. Due to the many changes during the course of the program many parts initially selected will be weeded out as a result of testing. The customer reviews numerous parts at present that will not be utilized in the final design,

Specifications are covered in the next section of this report (7.2.2).

Our documentation processing and review recommendations are as follows:

Recommendation 12:

All contractual data/documentation requirements should be carefully screened by NASA prior to imposition on the contractor to assure that documentation that does not directly affect NASA's interests or has a higher level requirement controlling it be submitted for information rather than for approval.

Recommendation 13:

Only design concept drawings should be specifically signed and approved by NASA. Manufacturing drawings should not require Government Representative signature as such signature does not connote approval and does not relieve the Contractor of his overall responsibilities.

REQUIREMENTS SPECIFICATION

For a given procurement, be it NASA procuring from a contractor, or a contractor purchasing from a subcontractor, the way the requirements for the item being purchased are specified can have a dramatic impact on the cost of the item. The cost can be incurred to a greater or lesser degree dependent upon the following factors:

- The choice of the type of specification and the matching of the content to the specification function
- The level of customer involvement and approval

In addition to these factors, there are, of course, savings that can be realized by intelligent specification preparation practices which minimize the cost of maintaining the documents as changes occur.

SPECIFICATION TYPES AND CONTENTS

MIL-STD-490 and MIL-S-83490 are the standards of the industry regarding specifica-

tions. They specify and provide outlines for five basic types of specifications, A - System, B - Development, C - Product, D- Process and E - Material. In addition, the first types A and B are subdivided into the following subsidiary types:

Development Specs	Product Specs
*B1 - Prime Item	*Cla - Prime Item Function
*B2 - Critical Item	*C1b - Prime Item Fabrication
B3 - Non Complex Item	*C2a - Critical Item Function
B4 - Facility or Ship	*C2b - Critical Item Fabrication
B5 - Computer Program	C3 - Non Complex Item Fabrication
	C4 - Inventory Item
	C5 - Computer Program

These types represent a "shopping list" from which the appropriate specifications for a given situation are chosen. For purposes of our discussion, we have focused on the following specifications, and in particular those in the first two categories which are asterisked above:

Development Specifications - Define the "design-to" requirements for an item to be developed. The essence of this type of specification is the item's performance, form factor and other pertinent technical considerations

Product Specifications - In addition to the performance and design requirements these specs define the "build to" and "test-to" requirements. They may be part II of a two-part specification, the first part of which is the Development Spec.

Materials and Process Specifications - State the requirements for materials and techniques and procedural requirements applicable to materials or fabrication processes. These are subsidiary specifications which are referred to in the higher tier specifications or on the implementing engineering drawings. Test specifications are included in this category.

The factors (cost drivers) which are controlled via these specifications and impact the ultimate cost of the item being procured, are illustrated in Figure 4-2. In the typical case examined, an estimate of the non-recurring and recurring (production) cost pertur-

bated by the stringency of the requirements specified in the Development/Product and subsidiary Material, Process and Test Specifications is broken down as follows:

Non-Recurring Cost:

Tooling (20%)

Dependent upon the complexity of the design and the depth of detail to which it is specified. If the Contractor has sufficient design freedom he may be able to reduce the testing cost.

Design, Development, and Test Engineering (43%) Dependent upon the stringency of the requirements for design and test criteria and the Quality and Reliability requirements stated in the specifications. Costs will vary depending on the Contractors capability to meet the requirements as specified. It is axiomatic that if he is given freedom to determine the 'how', he can utilize his capability in the most efficient manner.

Recurring Cost:

(100% Production Costs) Dependent on the design, tolerances, materials and acceptance test requirements. The more stringent and restrictive these requirements are, the higher the cost will be.

There is a tendency when preparing specifications to overspecify the requirements based on the technical knowledge of the preparer and on his experience. This detail is practical and appropriate when an item is being reprocured, and must be identical. But when development of an item is being procured, broader, non-restrictive requirements enable the Seller to make most efficient use of his capabilities. This is particularly important in a design-to-cost environment. On one recent program, which covered a broad range of equipment including missile, optical, armament, computers, and displays, procurement costs for sub-contracted items were reduced by an average of 20% by substituting "functional" requirements for the detailed design requirements originally specified.

We offer the following recommendations related to specification-type and content:

Recommendation 14:

Whenever possible, utilize Functional specifications stating performance only as opposed to Detailed Design Requirements in accordance with the following guidelines:

Use Development (Design Control) Specifications for any item below the system level whenever it is considered sufficient to specify performance only (as opposed to fabrication). Normally, the design control specification is used when:

- A single procurement (that is, one source) is anticipated or when training and logistic considerations are not important, or control of interchangeability of internal parts is either unnecessary or not desired.
 - It is necessary to specify performance as a first step in developing a product fabrication (detail design) specification. The transition to a fabrication specification is greatly facilitated by the existence of a development (design control) specification.

Performance requirements should be stated in quantitative terms only, that is, in terms of numerical inputs and outputs including permissible tolerances undervarious operating conditions as applicable. The reason for this is that:

- This is the only way performance values and tolerances can be established and verified for use in the attendant test or checkout procedure. In the case of the specification defining the preproduction configuration, these values and their tolerances serve as the basis for establishing the performance criteria of the equipment under the various environmental conditions of the qualification test.
- Any development specification should be void of 'how-to' design details since such details will only inhibit the designer's function by telling him how to do something instead of stating the end result he is required to achieve. This type of information belongs in the fabrication specification. The development specification should not contain philosophy and descriptive matter but should instead devote itself to exact statements based on a black-box concept, that is, list only inputs, outputs, and interfaces without concern for principles of operation. An exception is when for a valid technical reason part of all of the detail design has to be dictated. In general, specification of design details should be kept to a minimum.

Product Fabrication (Detail Design) Specifications are applicable to any item below the system level (including computer hardware), and are oriented toward procurement of a product through specification of primarily fabrication (detail design) requirements. This specification should be used for second source procurement, or re-procurement, that is, when it is necessary to make available a design disclosure package, to control the interchangeability of lower-level components and parts, and when service, maintenance and training are significant factors. This specification shall state:

- (a) A detailed description of the parts and assemblies of the product, usually by prescribing compliance with a set of drawings.
- (b) Those performance requirements and corresponding tests and inspections necessary to assure proper fabrication, adjustment, and assembly techniques.

In those cases where a development (design control) specification has been prepared, specific reference to the document containing the performance requirements for the item shall be made in the fabrication specification. Tests normally are limited to acceptance tests in the shop environment consisting of selected performance requirements and verifying tests. Preproduction-type or periodic tests to be performed on a sampling basis and requiring service, or other enivironment may reference the associated development specification.

Recommendation 15:

Eliminate "How-to" information from Process Specification leaving the methodology to the selection of the subcontractor. Whenever possible, reference broader Military or NASA documents in lieu of contractor process specification.

A contractor process specification is required only when the customer specification covering the applicable requirements is not detailed enough for the required process control. The process specification is essentially a general specification and is therefore applicable only to the extent specified on the design drawing or in the equipment specification. Manufacturing or process specifications should not be referenced to the point of inhibiting manufacturing technology or initiative. By imposing detailed specifications on sellers, for instance, the seller may be forced to deviate from his normal methods with no actual improvement in the end result. In all cases the emphasis should be on design conformance not methodology, keeping in mind that the purpose of a drawing upon which the process spec is referenced, is not to control production but rather to control the design configuration and to present the criteria for determining whether the item conforms to the stated requirements.

Recommendation 16:

Encourage the reduction of testing, assessment and analysis when advantage can be taken of previous work of a similar nature.

Recommendation 17:

Eliminate or greatly reduce whenever feasible general specifications for such things as Human Factors, Safety, Reliability, Maintainability, etc. and substitute broader functional requirements giving the seller flexibility in how he will demonstrate meeting them. This procedure will also reduce specification maintenance cost. A general specification covers requirements common to two more types, classes, grades, or styles of products, services, or materials. This avoids repetition of common requirements in other specifica-

tions. It also permits changes to common requirements to be readily effected. General specifications may also be used to cover common requirements for weapon systems and subsystems, such as reliability, maintainability, human factors weight control programs, etc., as well as sealing, watertightness, and certain finish requirements.

One of the most important things to remember about this type of specification, if it is to be imposed on sellers, is that the temptation to reorganize the seller's house must be resisted. In most cases, the sellers are capable of complying with general requirements imposed on them. As a rule, it is far more economical to be general enough to permit the seller to use his own detailed organizational setups and methods as long as he meets the end requirements. To require the seller to do everything the buyers way can be phenomenally costly. In addition, the use of general specifications require extreme care in the following areas:

- (a) Whenever reference is made to general specifications in equipment or other specifications, such reference should be made by specific paragraph number. Theoretically, it is true that if you say "welding shall be in accordance with SPG024", it is intended that he comply with whatever paragraph of that specification deals with welding. He usually suspects, however, that the welding requirements may be scattered (and unfortunately he is usually right) and therefore hangs a high price tag on the item to cover the requirements that he hasn't found yet. Also, requirements traceability is greatly aided by referencing specific paragraph numbers.
- (b) Unless these documents are carefully written it becomes difficult to separate a technical task from its associated data task. If for some reason the two tasks are not properly separated, a downstream economy measure to, for example, eliminate the data requirement may result in elimination of both tasks without intending to do so. For instance, a general reliability specification may contain a paragraph with the heading "3.2.1 Failure Analysis Report". If both the technical and the associated data requirement are stated in this paragraph, elimination of the report from the purchase order would automatically eliminate the technical task of conducting failure analysis as well as the report. To avoid this problem, the two requirements must be separated as follows:
 - "3.2.1 Failure Analysis. -
 - 3.2.2 Failure Analysis Report. -"

CUSTOMER APPROVAL LEVELS

The discussion of the appropriate level of approval of specifications follows generally the argument advanced above. Recognizing that the degree of customer involvement in the affairs of a contractor is related to the degree of risk that the Government can accept, we do not advocate reduction of government cognizance over areas in which his interest is involved. Rather our recommendations deal with the review and approval of specification requirements which are a level below those which protect the Government's interest.

Figure 4-3, Document Control Levels, illustrates this point. The specification at the subsystem level contains all of the performance requirements necessary for Government approval, and the Government will accept or reject the contractor's delivered items on this basis. There is in reality little to be gained by Government approval of specifications below this level. Surveillance and visibility can still be retained, but the time-delaying repetitive effort in reviewing and approving iterating requirements allocated to these lower levels can be eliminated. Government participation in such activities as the contractor's configuration reviews and audits of his sellers can provide a more meaningful barometer of design progress and requirements compliance.

Recommendation 18:

Limit customer approval to System/Subsystem Level, with Contractor control on the Black-Box (Equipment) Specification level. This will provide greater flexibility and timeliness in contractor-subcontractor relations and will contribute to lower costs. The System and Subsystem Level Specifications should contain only top-level performance and interface requirements with the lower tier documents being selectively more detailed.

4.7 BASELINES AND CONFIGURATION CONTROL

In any discussion on cost saving methods of documentation and controls, the subject of changes and change controls cannot be ignored. For regardless of initial contract cost, if good controls are not placed on changes, the costs will escalate. This is not to say that changes should be avoided. Some are necessary, and are beneficial to the program. Some changes can reduce the acquisition cost of the product, or its total life cycle costs.

In the normal application of Configuration Management to a program emphasis is often placed on obtaining a product baseline as early as possible to have full control of the configuration and all changes and thus hold down costs. This misconception, as we will see, is the very reason some past programs have been caught in a time-wasting and costly change mill.

Experience on many aerospace programs of varying scope and complexity over the past 10 to 15 years has shown us the types of change board activities on both the contractor and the Government that are efficient and effective, and those which 'prolong the agony.' Grumman's advocacy of an early-in-the-game 'joint' board stems from our confidence in ourselves and our philosophy of frankness and openness with our customer.

OPTIMUM BASELINING - In a well-managed configuration management program, the configuration of the hardware and documentation are known at all times from the first specification release to the delivery of the last article under the contract, so there is no real magic to the establishment of a configuration baseline. There are in reality two configuration baselines which evolve as the program progresses: one is the internal contractor baseline represented by all of the specifications and drawings he has released; the other is the formal baseline represented by the documentation/hardware approved and accepted by the customer. To this second baseline, we give names like Functional Allocated and Product to represent the level of coverage. The Product Baseline occurs when the two baselines merge; i.e., the complete design disclosure package is subject to customer change control.

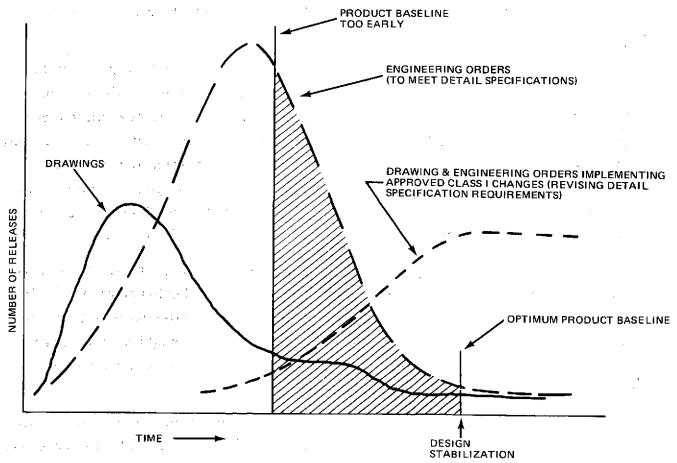
If this point is selected too late, the customer loses the ability to make decisions about changes which may be costly and may impact his associated support training and operational activities if not the contract costs itself. If chosen too early, an unnecessary and burdensome "change mill" is created merely because the product was baselined before the point of design stabilization. The inevitable iterations and changes resulting from initial manufacture and testing are within the province of the contractor's work scope in meeting his specification requirements. It is only when these changes begin to impact delivered equipment (retrofit required), support commodities, logistics, etc., that they should properly be under the province of customer change control. The precise point in the program cycle is a variable, highly dependent on individual program circumstances. It is determined by trading-off the program milestones, i.e., delivery, flight schedule, testing schedule, against the anticipated change profile, and the need for provisioning, logistic support and maintenance information. It must be recognized that few programs

are ideally paced, most are constrained by external influences such as operational objectives, mission windows, critical shortages, funding limitations, etc.

Figure 4-4, Optimum Baseline, is a typical aerospace program profile of the release of drawings and Engineering Orders. The following parameters are plotted:

- The release of drawings to meet System/Detail Specification requirements
- The release of changes (Engineering Orders) correcting or revising the original releases in order to meet the Spec requirements
- The release of EO's implementing Class I Changes initiated by the customer or contractor.

The optimum product baseline occurs at or near the point of design stabilization.



OPTIMUM BASELINE OCCURS AT THE POINT OF DESIGN STABILIZATION. BASELINING TOO EARLY RESULTS IN DESIGN CHANGES (SHADED) BEING SUBJECTED TO UNNECESSARY CHANGE CONTROL.

Fig. 4-4 Optimum Baseline

The following recommendations are offered with regard to the establishemnt of the product baseline.

Recommendation 19:

Select the point in the Program for establishment of the product baseline at or near the point of design stabilization to avoid an unnecessary and burdensome change mill.

Recommendation 20:

Dependent upon overall program schedule, portions of the system should be baselined independently at an optimum point for that segment.

Recommendation 21:

Since the program schedule itself is the prime cost driver in the change control process, exercise caution that the program is properly paced with regard to development effort and design stabilization.

CONFIGURATION CONTROL - Once a change has been conceived, the longer it takes to process it, and nurture it to the point of implementation, the costlier it will become. This is particularly true with changes which correct deficiencies, because while a condition goes uncorrected, progress may be halted, interim solutions and workarounds may be devised and operating limitations formulated. Lengthy processing results in more retrofit, which is usually more expensive than implementing a change in the production flow. Hence it is obvious that speedy processing of changes by both the contractor and the Government would tend to decrease overall costs.

We have found, notably on the OAO, LM and F-14 Programs, that one way to speed change processing is to provide better and more direct communication on changes. On the NASA/Grumman OAO Program, Grumman utilized the same changes documentation for submittal of changes to the procuring activity as it did for processing internal changes. This procedure has the advantage of simplicity. It also eliminates the requirement of reworking a change directive merely for the sake of format.

On LM and F-14, the concept of joint customer and contractor change boards have been successfully applied. In the later days of the LM Program, the CCB was convened by conference telephone call in many instances. On the F-14, we have recently instituted a joint mini-board which convenes regularly to screen potential changes. What this board accomplishes is to eliminate early in the change process those changes that would eventually have been disapproved later by the customer.

4

Based on these positive experiences, we are ready to offer the following recommendations for EOS consideration:

Recommendation 22:

Establish the System Interpretation Configuration Control Board (SICCB) to review, discuss and expedite change processing.

Recommendation 23:

The SICCB will screen potential changes prior to the commitment of them to proposal preparation, to determine if the contractor should proceed with further effort or discontinue.

Recommendation 24:

Conference calls between appropriate NASA and Grumman program managers, with supporting personnel in attendance at either end of the conversation, can be utilized to minimize travel and expedite change action.

Recommendation 25:

While rigorous documentation of changes is necessary, we believe that an Engineering Change Proposal format that is the same as the paperwork used internally for change processing can be utilized by NASA. This format will be specifically tailored to the EOS Program and mutually agreed upon.

Recommendation 26:

In the design-to-cost environment, the S.I. will find changes which reduce cost to counterbalance proposed changes which increase cost. Cost versus performance and requirement trade-offs will be made continuously throughout the program.

Recommendation 27:

One reason that change processing in government agencies takes as much time as it does is the frequent lack of one central fiscal authority over the funding of all aspects of a change. Though this has been less a NASA problem than, say the Navy, it is a trap that should be avoided in the future.

Recommendation 28:

Mutual confidence results from the identification, visibility, and prompt solution to problems. NASA's knowledge that the Contractor is not hiding problems but solving them, as evidenced in the (SICCB) recommendations, will enhance this confidence and make excessive documentation and controls unnecessary.